Awwa Research Foundation
Advancing the Science of Water®

EPA

Asset Management Research Needs Roadmap

Subject Area:
Efficient and Customer-Responsive Organization

Asset Management Research Needs Roadmap

Awwa Research Foundation

About the Awwa Research Foundation

The Awwa Research Foundation (AwwaRF) is a member-supported, international, nonprofit organization that sponsors research to enable water utilities, public health agencies, and other professionals to provide safe and affordable drinking water to consumers.

The Foundation's mission is to advance the science of water to improve the quality of life. To achieve this mission, the Foundation sponsors studies on all aspects of drinking water, including supply and resources, treatment, monitoring and analysis, distribution, management, and health effects. Funding for research is provided primarily by subscription payments from approximately 1,000 utilities, consulting firms, and manufacturers in North America and abroad. Additional funding comes from collaborative partnerships with other national and international organizations, allowing for resources to be leveraged, expertise to be shared, and broad-based knowledge to be developed and disseminated. Government funding serves as a third source of research dollars.

From its headquarters in Denver, Colorado, the Foundation's staff directs and supports the efforts of more than 800 volunteers who serve on the board of trustees and various committees. These volunteers represent many facets of the water industry, and contribute their expertise to select and monitor research studies that benefit the entire drinking water community.

The results of research are disseminated through a number of channels, including reports, the Web site, conferences, and periodicals.

For subscribers, the Foundation serves as a cooperative program in which water suppliers unite to pool their resources. By applying Foundation research findings, these water suppliers can save substantial costs and stay on the leading edge of drinking water science and technology. Since its inception, AwwaRF has supplied the water community with more than $300 million in applied research.

More information about the Foundation and how to become a subscriber is available on the Web at **www.awwarf.org.**

Asset Management Research Needs Roadmap

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FOREWORD

The Awwa Research Foundation is a nonprofit corporation that is dedicated to the implementation of a research effort to help utilities respond to regulatory requirements and traditional high-priority concerns of the industry. The research agenda is developed through a process of consultation with subscribers and drinking water professionals. Under the umbrella of a Strategic Research Plan, the Research Advisory Council prioritizes the suggested projects based upon current and future needs, applicability, and past work; the recommendations are forwarded to the Board of Trustees for final selection. The foundation also sponsors research projects through the unsolicited proposal process; the Collaborative Research, Research Applications, and Tailored Collaborations programs; and various joint research efforts with organizations such as the U.S. Environmental Protection Agency, the U.S. Bureau of Reclamation, and the Association of California Water Agencies.

This publication is a result of one of those sponsored studies, and it is hoped that its findings will be applied in communities throughout the world. The following report serves not only as a means of communicating the results of the water industry's centralized research program but also as a tool to enlist the further support of the nonmember utilities and individuals.

Projects are managed closely from their inception to the final report by the foundation's staff and large cadre of volunteers who willingly contribute their time and expertise. The foundation serves a planning and management function and awards contracts to other institutions such as water utilities, universities, and engineering firms. The funding for this research effort comes primarily from the Subscription Program, through which water utilities subscribe to the research program and make an annual payment proportionate to the volume of water they deliver and consultants and manufacturers subscribe based on their annual billings. The program offers a cost-effective and fair method for funding research in the public interest.

A broad spectrum of water supply issues is addressed by the foundation's research agenda: resources, treatment and operations, distribution and storage, water quality and analysis, toxicology, economics, and management. The ultimate purpose of the coordinated effort is to assist water suppliers to provide the highest possible quality of water economically and reliably. The true benefits are realized when the results are implemented at the utility level. The foundation's trustees are pleased to offer this publication as a contribution toward that end.

David E. Rager
Chair, Board of Trustees
Awwa Research Foundation

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Participating Utilities:

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City of Bellevue Utilities Department; Bellevue, Washington
City of Calgary Water Resources; Calgary, Alberta, Canada
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City of Clearwater Public Utilities; Clearwater, Florida
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DuPage Water Commission; Elmhurst, Illinois
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Henrico County Department of Public Utilities; Richmond, Virginia
Hillsborough County Water Resources Services; Tampa, Florida
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York Region Transportation and Works; Ontario, Canada

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Cleveland Water; Cleveland, Ohio

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Water Environment Research Foundation
Polytechnic University; New York, New York
United Utilities Water Services, United Kingdom
US Environmental Protection Agency
US Federal Highway Administration
American Water Works Association

In addition, Maureen Hodgins, AwwaRF Project Officer, helped design the research effort. Her advice and help, plus the advice and help of the Project Advisory Committee (PAC) – including Andrew DeGraca, San Francisco PUC; Dr. Neil Grigg, Colorado State University; Scott Haskins, Seattle Public Utilities; Ron Lovan, Northern Kentucky Water District; and Yakir Hasit, CH2M Hill – were instrumental in making this project a success.

The authors wish to acknowledge the assistance of Anne Smith of Smith Culp, who facilitated the workshop; June Lowther of American Water for her skillful coordination of the workshop; and Julie Self of HDR Engineering for her efforts in coordinating the workshop logistics and preparing the final report.

EXECUTIVE SUMMARY

AwwaRF has been conducting research on drinking water infrastructure assets for over 40 years. Much of this work has been accomplished with AwwaRF's own funding and some work has been in collaboration with other entities. AwwaRF, seeing a need to review the status of asset management in North America as it relates to drinking water infrastructure, commissioned this project to develop an Asset Management Research Needs Roadmap to guide future AwwaRF endeavors.

Asset management (AM) covers a utility's assets from "source to tap" and includes both aboveground facilities and underground assets. The assets that need to be managed in a sustainable manner include dams, reservoirs, diversions, wells, well fields, treatment facilities, transmission and distribution lines, valves, hydrants, control valves and related systems, meters, finished water storage facilities, cross connection control devices, sampling taps, all system appurtenances, instrumentation and control systems, data and information technology, buildings and structures, shops, real estate, and more. Aboveground facilities are normally easier to assess and maintain than their underground counterparts and therefore have historically received more attention.

A sustainable, life-cycle management approach is key to a good AM program. There are many benefits to be derived from AM including reduced risks from failure of key system components, transparent justification for rate structures, more reliable water supply, better water quality, and compliance with regulatory requirements, just to name a few.

Research projects and associated Requests for Proposals (RFPs) are developed in many ways and originate from a variety of sources. The project descriptions and future AM RFPs from this AwwaRF Research Roadmap Project 4002 follow the flowchart depicted in Figure ES.1 from concept to potential funding. The three major parts that are shown in Figure ES.1 include: Part I-Gathering Background Information, Part II-Developing the Research Roadmap, and Part III-Implementing the AM Projects. The Project Advisory Committee (PAC), the AwwaRF staff, and the project team worked closely throughout the project to ensure that practical, useful research activities would result.

In Part I, the project team gathered background information by developing a White Paper, documenting case studies, and conducting AM utility interviews. AM needs were determined and those that could be addressed by AwwaRF research were identified. In Part II, a major workshop was held with over 50 participants from operating utilities, consultants, academia, government, and other research organizations. At the workshop, over 100 research gaps were identified and some 23 preliminary research projects and ideas were initially developed by the workshop participants. In an interactive process, the project team and PAC then consolidated those research ideas and descriptions into the following six research areas:

Research Area 1: Asset Management Framework/Models for Organizations (3 projects)
Research Area 2: Risk Management (1 project)
Research Area 3: Condition Assessment and Performance Monitoring (2 projects)
Research Area 4: Decision Making for Capital Improvement Programs (CIP) and Replacement and Renewal (R&R) (3 projects)
Research Area 5: Asset Management Information Technology (IT) and Data Management (2 projects)
Research Area 6: Operation and Maintenance Practices (1 project)

Within these six research areas, twelve projects were developed in more detail, project descriptions were refined, budget estimates were prepared, and potential partnering organizations were identified. The PAC prioritized these twelve projects and four were ranked highly and recommended for immediate consideration by the AwwaRF Research Advisory Council:

- Prepare Guidance Manual for Level of Service and Metrics – $300,000 (Research Area 1)
- Central Repository of Asset Data to Support Maintenance, Repair, Rehabilitation, and Replacement for Water Mains – $100,000 (Research Area 4)
- IT Integration and Data Model to Support AM – $550,000 (Research Area 5)
- Guidance Document for Best Maintenance Practices for Water Distribution Assets – $400,000 (Research Area 6)

In Part III, the Research Advisory Council will conduct the annual deliberations that result in recommendations for ultimate approval and funding by the AwwaRF Board of Trustees. As indicated on Figure ES.1, the AM projects developed as part of this AwwaRF Project 4002 will enter a larger pool of project proposals for consideration by the Research Advisory Council. Thus, there is no guarantee that even the top four projects listed above will be approved by the Board of Trustees for funding.

In summary, extensive utility participation led to the practical, 5-year research agenda described in this report. The heart of the AM Research Roadmap consists of twelve detailed project descriptions, a prioritized ranking by the PAC with four top-ranked projects, a 5-year schedule, estimated budgets for the projects, and in some cases potential partners for collaboration. While many of the projects are interrelated and should be conducted in a sequence to be most efficient, others are standalone projects. It will be important to check progress on both AwwaRF AM projects and those conducted by other entities on a continuous basis. Much work is being done on the subject both nationally and internationally by others and AwwaRF should continually search for potential partners in this AM arena.

AwwaRF Update 2008

After months of research planning for AwwaRF's 2008 Solicited Research Program, about half of the high priority projects were funded. Four or five project ideas suggested by the *Asset Management Research Roadmap* were developed into the following projects and won funding for 2008.

- Organizational Models, Cultures, Policies and Strategies for Effective Water Utility AM Program Implementation
- Condition Assessment of Water Main Appurtenances
- Key Asset Data for Water Utilities
- Participation in UKWIR's "Failure Data and Analysis Methodology for Water Mains"

Other highly ranked project ideas from the *Asset Management Research Roadmap* will be considered in the future, after similar ongoing work is completed.

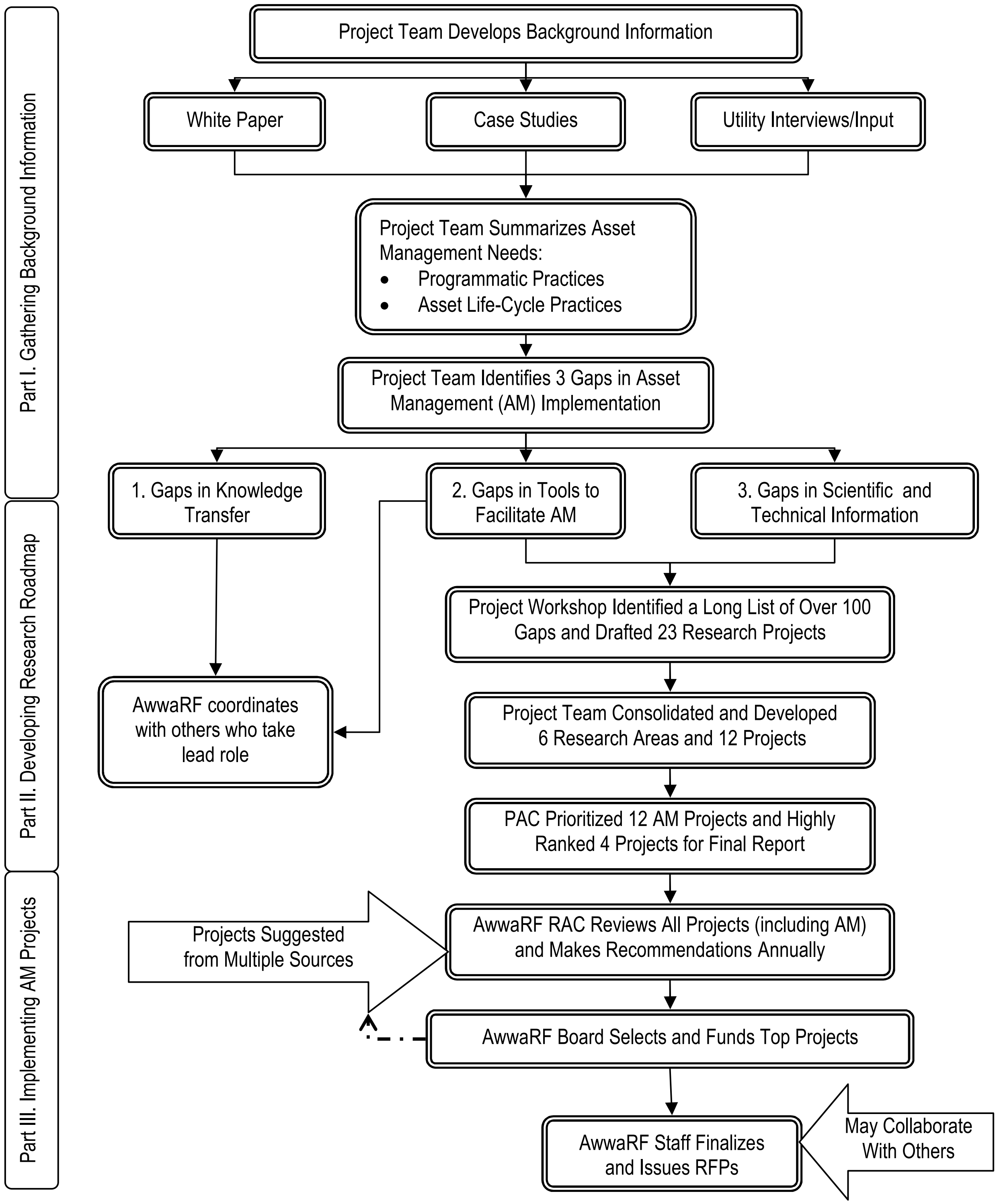

Figure ES.1. Developing and Funding Requests for Proposals – How This Roadmap Fits Into the Solicited Proposal Process

CHAPTER 1
INTRODUCTION

BACKGROUND

Water and wastewater utilities own and operate extensive inventories of equipment, facilities, and infrastructure. Owning and operating these assets presents continual challenges to utility managers. For most water and wastewater utilities, the basic mission is to provide high-quality service at an affordable cost; however, costs tend to rise as the infrastructure ages. North American water and wastewater utilities are funded, for the most part, by user fees in the form of rates and charges. With rare exceptions, these rates and charges do not recover the full, true cost of asset ownership. As a result, drivers such as aging infrastructure, growth, shifting population patterns, and changing regulatory requirements place increasing importance on implementing the most cost-effective means of infrastructure and system ownership and operations. Increasingly, the set of practices and tools applied to these vexing problems is characterized as "asset management."

Asset management has been defined as an integrated optimization process of "managing infrastructure assets to minimize the total cost of owning and operating them, while continuously delivering the service levels customers desire, at an acceptable level of risk" (AMSA et al. 2002). While this definition is useful to convey a general concept, there has never been a consensus in the North American water and wastewater industries regarding the programs and practices required to successfully implement this definition of asset management. There are other definitions, but all tend to have in common the elements of managing both capital and operations costs on a life-cycle basis, providing adequate service, and managing risk at acceptable levels.

Within the broad definition of asset management, a range of specific practices can be identified. Assets must be identified, located, and tracked. Condition and performance must be monitored over time. Standards of acceptable performance must be established. Maintenance practices must be planned and executed, and capital planning must take into account risk, costs, and benefits. All of these practices, and more, are encompassed within the field of asset management. In a sense, asset management constitutes "systems thinking;" that is, addressing the myriad of elements and processes that make up a modern water or wastewater utility as one interrelated system to be managed, optimized, and maintained to achieve the owner's goals.

Asset management applies to industries as diverse as transportation, electric power, and manufacturing. Like the water and wastewater industries, these industries must invest in long-lived capital facilities that meet critical service and reliability objectives. A body of asset management research has emerged in each industry. Guides such as the *International Infrastructure Management Manual* (IPWEA 2006) describe asset management principles that can be applied across a variety of industries and settings. American water and wastewater utilities have drawn upon a wide range of asset management experiences and resources from other industries. However, an accepted, standard "best practices" approach to asset management for water and wastewater utilities remains to be formulated.

AWWARF'S ROLE IN FURTHERING ASSET MANAGEMENT

Since the late 1990s, AwwaRF has funded studies on topics related to asset management. In addition, AwwaRF has collaborated with other organizations in many of these efforts, including the Water Environment Research Foundation (WERF), United Kingdom Water

Industry Research Limited (UKWIR), Commonwealth Science and Industrial Research Organisation (CSIRO) of Australia, National Research Council (NRC) of Canada, the Netherlands organization Kiwa Water Research, and others. AwwaRF's participation in the Global Water Research Coalition (GWRC) has facilitated communication and sharing of resources among these organizations.

AwwaRF summarized the need for this Asset Management Research Needs Roadmap in its March 2006 Request for Proposal (RFP), which stated in part:

> *"…many utilities are uncertain about AM (Asset Management), have delayed or scaled down implementation efforts, and do not see a clear path for embarking on a comprehensive AM program. There is currently no strategic industry focus for the planning and funding of future research efforts in the area of asset management for water and wastewater utilities."*

In summarizing the goals of this project, the AwwaRF RFP requested that the project:

> *"...assemble key organizations and experts to evaluate the available asset management information and identify future water and wastewater community needs which research could help solve. It will summarize the asset management landscape, identify critical information gaps, develop research project ideas, and generate a strategic approach for the funding of research to fill the gaps."*

This project has generated two primary "products" in response to AwwaRF's request:

1. A comprehensive White Paper documenting the current state of asset management among North American water and wastewater utilities; and
2. A Research Roadmap, comprising a multi-year prioritized strategy for future asset management research for consideration by AwwaRF's staff, the Research Advisory Council (RAC), and Board of Trustees.

The full White Paper is attached as Appendix A. This report presents the Research Roadmap.

PROJECT APPROACH

To achieve the goals listed in the previous section, the HDR/Westin team collaborated with the Project Advisory Committee (PAC), AwwaRF staff, and many participating utilities to perform the activities described below (see Figure 1.1).

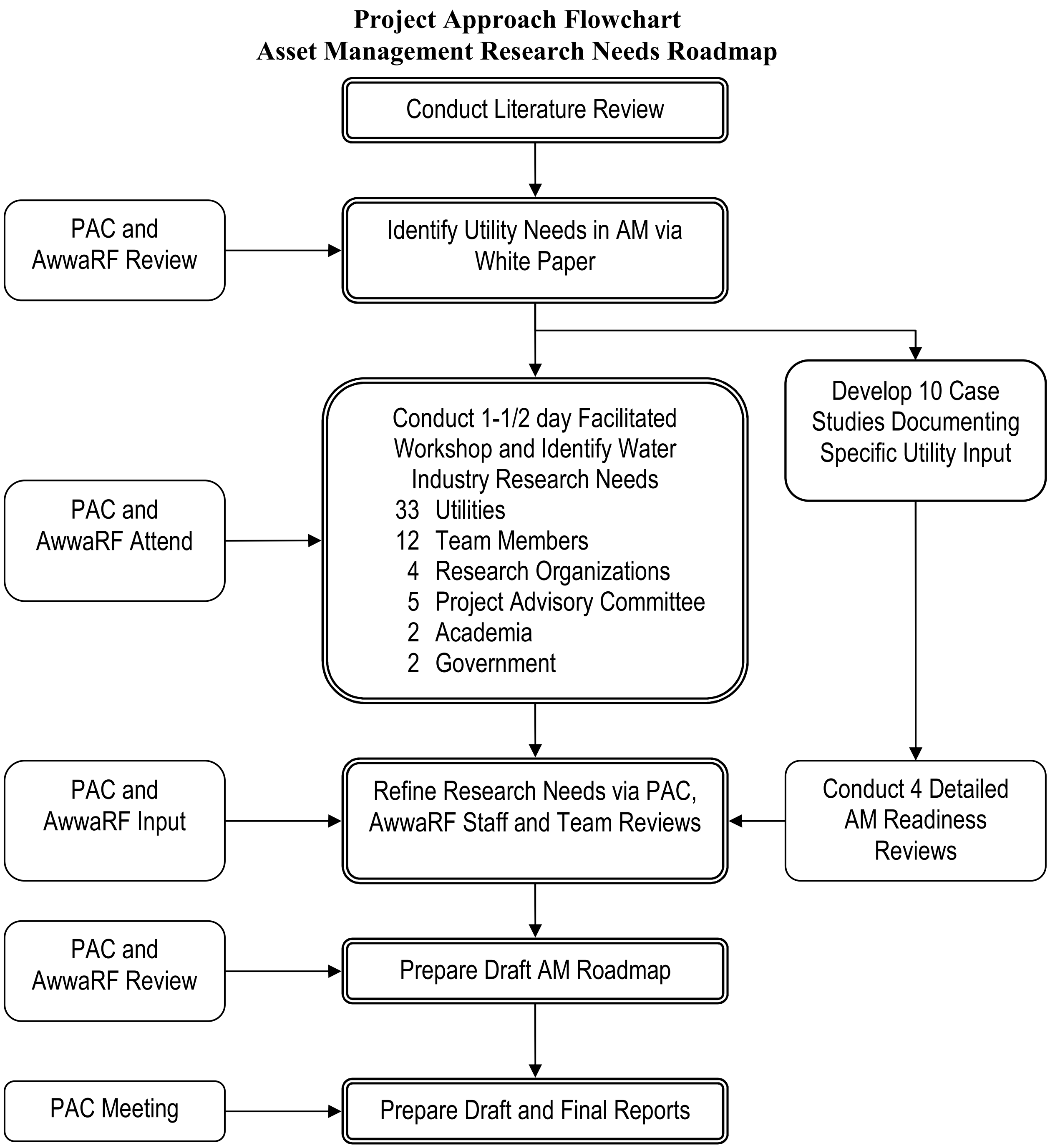

Figure 1.1. Flowchart of Activities to Develop the Research Roadmap

The team performed a **literature review** to identify and describe the major elements of asset management in multiple industries, with particular focus on the North American water and wastewater industries. The review also identified research activity that is currently underway or planned by a variety of other organizations.

The team prepared a **White Paper** (Appendix A) that summarizes the core practices associated with asset management, describes the extent to which these practices are being applied, and identifies key gaps in research and understanding. This White Paper was developed from the literature review and shared with the team's participating partners in preparation for the workshop that followed. In developing the White Paper, the HDR/Westin team identified a range of needs and gaps facing North American water and wastewater utilities. These needs and gaps were grouped into three categories:

1. Gaps in knowledge transfer
2. Gaps in the "tools" of asset management
3. Gaps in scientific or technical knowledge and understanding

The team then identified a wide variety of specific research projects and activities that are currently underway or pending, designed to address needs within these three categories. Table 6.1 of the White Paper (Appendix A) summarizes this assessment of gaps and ongoing research efforts.

A **workshop** was convened and attended by over 50 utility managers, asset managers, and representatives of other industries such as transportation and power to discuss the White Paper findings and to develop concepts for future research projects. A workshop summary is attached as Appendix B.

Ten case studies were developed to gather current information from utilities on asset management practices. Case studies consisted of an initial telephone contact, followed by face-to-face meetings with managers responsible for asset management activities. Each case study was reviewed and approved by the utility as a condition of publication. The outcomes from the case studies were used to validate findings and develop trends in asset management. The case study write-ups for American Water, Anchorage Water and Wastewater Utility, Charleston Water System, District of Columbia Water and Sewer Authority, DuPage Water Commission, Henrico County Department of Public Utilities, Long Beach Water Department, Los Angeles Department of Water and Power, Louisville Water Company, and Newport News Waterworks are included as Appendix C.

Four additional asset management **readiness reviews** were conducted to take a more in-depth look at asset management practices and needs. These reviews consisted of (a) intensive, 2-day, onsite workshops involving top management and multiple program managers and staff at the respective utilities, and (b) review of a substantial volume of utility-provided supporting information. For this effort, the respective utility provided real dollar support to the project. The four utilities involved were: Cleveland Water, Denver Water, Tacoma Water, and York Region Transportation and Works (Ontario, Canada).

The team developed this Research Roadmap using the results from the literature review, White Paper, workshop, case studies, and readiness reviews. The Roadmap presents research recommendations for twelve projects in six research areas. Workshop participants rated these twelve projects highest in importance. This Roadmap also presents broad estimates of budget needs for each project. The projects are arranged in a time frame that takes advantage of sequential learning and manages costs within limits appropriate to AwwaRF's expected resources. This report summarizes the projects; more **detailed project descriptions** are attached as Appendix D.

This project benefited from an unusually high degree of involvement by numerous utilities and other participants. In fact, more than 30 utilities participated. In addition, the project was strengthened by the ongoing, substantive participation of a Project Advisory Committee (PAC) comprised of utility managers, academics, and consultants deeply involved in asset management in their daily work. Several AwwaRF staff members helped guide and support the project.

TRENDS AND NEEDS IN ASSET MANAGEMENT

The team identified the following primary trends and asset management needs for North American utilities based on outcomes and findings from the research activities, case studies, and readiness reviews.

Structured Asset Management to Support Capital Financing

North American water utilities face substantial funding needs for rehabilitating and replacing aging infrastructure. Most utilities do not have adequate reserves to fund long-term renewal programs. Ratepayers and utility boards are often unaware of the long-term financial costs that confront their systems. Many utilities have no structured, prioritized strategy or program to address this critical funding issue and no strategic program to educate the public and decision makers. To address these challenges, York Region Transportation and Works, one of the utilities that participated in the readiness review, prepares an annual Regional Business Plan and Budget to document current and upcoming initiatives for the next several years, including asset management initiatives. The Regional Business Plan and Budget provides an effective means to communicate priorities to the Regional Council, and provides focus to staff for key initiatives across the utility to ensure that activities are properly prioritized and aligned. It is also useful information for external stakeholders.

Cleveland Water, another of the utilities that participated in the readiness review, has taken a proactive approach with regard to financial planning. Cleveland ties its annual funding level to a well-defined Capital Improvement Plan. Operations, maintenance, and capital expenses are routinely covered in full, with aging water treatment plant facilities tending to receive priority in funding. Cleveland Water develops a 5-year forecast of operations, maintenance, and capital project expenses and develops a 5-year plan to address these needs. The utility recently completed a cost of service analysis and developed a financial planning model. The utility is not experiencing much “new” growth pressure, so the preponderance of the capital needs is for rehabilitation and/or replacement projects. Cleveland Water is currently experiencing a new challenge; namely, the utility is acquiring or plans to acquire ownership of suburban distribution systems. While Cleveland has already been providing retail service to these suburban systems, the transfer of asset ownership will also bring about capital investment responsibilities for the City that it has not previously borne, and this will present new challenges. Consolidations and formal operating agreements between wholesale and retail entities are becoming more commonplace as systems mature and rely more heavily on each other to address security, regulatory, and financial concerns.

Priority on Buried Assets

Buried pipelines and water mains account for the majority of the water industry's investment in assets, and these assets are difficult to access and inspect. The demand for rehabilitation and renewal of buried assets will significantly increase over the next several decades. Increased need will necessitate improvements in the tools, technologies, and methods used to monitor condition and performance, and drive the renewal of buried infrastructure. A knowledge base and understanding of failure rates of different classes of buried piping are needed. While aboveground assets are also critical and should be part of the asset management framework, these assets are easier to inspect and monitor.

Overall Asset Management Framework

As previously mentioned, asset management has more than one definition within the North American water and wastewater industries. While key concepts are becoming better known, strategies to effectively implement these concepts are not widely understood. Many other industries and international utilities have developed policy frameworks for asset management, such as the NRC Canada's *Framework for Municipal Infrastructure Management* (Vanier et al. 2006). US utilities need a conceptual framework for asset management policy and strategies that can be scaled based on size. While each utility will require unique application of policy, a common vocabulary, structure, and strategic understanding will make it easier for utilities to implement successful asset management programs.

Organization and Management

By and large, utilities are not structured to support the cross-functional activities and decision making that asset management requires. Utilities are typically organized in functional "silos," and require asset management practices and organization elements to provide integration across organizational functions. Without these attributes, it is difficult for organizations to prioritize expenditures based on sound asset management principles. Some utilities have developed management strategies or organizational structures that support asset management, but these are the exception rather than the rule. Utility organizations need support in developing and implementing more integrated, systematic organization structures and practices if they are to optimize the benefits of asset management.

Risk-based Asset Decision Making

Risk analysis is central to prioritizing asset maintenance, renewal, or investment. The use of risk-based asset decision making is common in many industries, such as electric power, and is beginning to evolve in North American water and wastewater utilities. Improved tools and skills specific to water and wastewater utilities need to be developed to perform risk assessment and risk management. Many utilities do not formally classify their assets on the basis of criticality, nor do they use this information to guide formal maintenance procedures. There is a need to develop risk management approaches that can be widely applied by utility personnel who do not have formal training in these protocols.

Demand for Data

Asset management is data intensive, requiring utilities to gather and store asset data over many years in numerous sources and systems (geographic information systems [GIS], computerized maintenance management systems [CMMS], Modeling Supervisory Control and Data Acquisition [SCADA], finance, etc.) that are typically neither fully integrated nor easily accessible. The need is ever increasing for a myriad of data types and sets that support asset decision making. Readily available asset management data models and integration solutions specific to water and wastewater utilities are highly desirable.

Economic Analysis

Life-cycle cost analysis for capital asset decisions is not commonly used in many utilities, but is evolving as a best practice in advanced asset management programs. To effectively perform cost analysis, advancements are needed in tools and skills, which are described more fully in Section IV below.

Distribution System Maintenance Practices

Maintenance practices for distribution system assets lag well behind the more advanced techniques used for rotating equipment and plant assets. Many distribution system assets are maintained reactively or run to failure. Improved operation and maintenance (O&M) practices are necessary to extend the life of existing assets so that capital investments can be directed toward high-priority assets.

CHAPTER 2
ASSET MANAGEMENT RESEARCH FRAMEWORK AND FINDINGS

ASSET MANAGEMENT RESEARCH FRAMEWORK

As part of the White Paper (Appendix A) prepared for this project, the team developed an idealized AM paradigm that includes programmatic and asset life-cycle practices. This paradigm, illustrated in Table 2.1, was used to compare idealized practices with the current state of asset management to identify gaps and opportunities for research. Programmatic practices are those that relate to the utility organization or asset management program as an enterprise. Life-cycle practices are those specific practices applied at any point in an asset's life from creation to operation to disposal.

Table 2.1
Paradigm for Asset Management Practices

Programmatic Practices	Asset Life-Cycle Practices
• Program Management and Organization Structure • Program Development and Evaluation • Data Systems and Information Technologies • Financial Practices	• Asset Creation • Operation and Maintenance • Physical Condition Assessment and Performance Monitoring • Asset Renewal • Asset Disposal

The team also developed a structured Asset Management Research Framework to facilitate industry discussion, analysis, and categorization of research. The six research areas presented in Table 2.2 were selected to encompass all aspects of the research framework, to support current research needs, and to provide for ongoing asset management research.

Table 2.2
Asset Management Research Framework

Research Area 1: Asset Management Framework/Models for Organizations
Research Area 2: Risk Management
Research Area 3: Condition Assessment and Performance Monitoring
Research Area 4: Decision Making for CIP and Replacement and Renewal (R&R)
Research Area 5: Asset Management IT and Data Management
Research Area 6: Operation and Maintenance Practices

During the workshop and subsequent analysis, the research framework was used to categorize research projects into logical groups and to address the prioritization of research across all research areas. The following section summarizes findings from each of these six research areas. Detailed project descriptions are contained in Appendix D to this report.

FINDINGS

Research Area 1: Asset Management Framework/Models for Organizations

The purpose of asset management is to make sound decisions about all aspects of owning, operating, and maintaining physical assets such as utility infrastructure and equipment. Many of these assets are long-lived, and the necessary multi-faceted decisions engage many types of expertise across all functions of an organization. Therefore, decisions are made by different combinations of people throughout an organization over many years and decades. Decision making under these circumstances can easily become fragmented and reactive. Policy frameworks and organizational models within utilities can either foster sound asset management or create obstacles that undermine its goals.

The project team identified a lack of available policy frameworks and organization models that North American utilities could use to implement an asset management program. The case studies and workshop activities demonstrated that few North American utilities have implemented a comprehensive asset management framework to define policy and set strategies. While most utilities are addressing asset management at some level, a majority of case study utilities have relatively informal programs at this time. In addition, a wide variety of organizational models are used, although many utilities have designated asset managers.

Many of the case study utilities do not have a formal vision statement for their asset management program. One notable exception is Henrico County Department of Public Utilities, which has this well-defined vision statement:

> *"The Henrico County Department of Public Utilities will deploy an integrated, state-of-the-art system to align business processes with Best Practices in Enterprise Asset Management."*

Each element (i.e., phrase) in the vision statement implies specific objectives for Henrico County's asset management program. Since this vision's creation, it has provided guidance on asset management matters for Henrico County's management team. The statement's objectives are reflected in planning for capital improvements, rehabilitation and replacement priorities, preventive program resources, and daily management decisions.

The case studies offer examples of utilities that see value in setting policies, tracking performance measures, and using other management tools to optimize the effectiveness of asset management programs. For example, Anchorage Water and Wastewater Utility identified improved use of key performance indicators (KPIs) and review of customer service levels as important areas for its program.

During the readiness review conducted with York Region Transportation and Works (York), it was noted that the York serves one of the fastest growing regions in Canada. As such, York's capital concentration has been and will remain focused on growth. To address this rapid growth, York developed a unique approach with two capital plans: a 10-year Master Plan of about $240 million per year for growth, and a Minor Plan for rehabilitation and replacement of about $15 to $20 million per year. Minor capital is based on a 5-year plan but is capitalized over 10 years.

The White Paper in Appendix A identifies attributes of utility organizations that contribute to an effective asset management program. These include:

- **Vision,** established with a long-term view matched to asset lifetimes;
- **Organizational culture** that fosters communication and decision making across functional boundaries;
- **Asset performance measures** tracked and communicated throughout the organization; and
- **Human resources recruitment and training** aligned with program objectives.

The White Paper also indicates that many utility organizations in North America do not exhibit all of these attributes, and this may hamper their ability to build effective asset management programs. Indeed, some involved in the water and wastewater industries suggest that the biggest hurdles facing asset management in North America are not technical, but organizational (WERF 2002).

Regarding cultural and organizational changes, DuPage Water Commission offered the following advice:

> *"The basis of the Asset Management Program implementation was change management and awareness at all levels of the organization. Commission management brought recognized leaders in asset management on-site to convey best practices and provide an understanding of why it is important, and how to achieve success. The success of this implementation will not be due to the software or a star project performer, but rather the understanding and acceptance of change within the organization driven by asset management requirements."*

At the workshop held for this project, participants agreed that asset management frameworks, policy development, and organizational models were vital elements of asset management programs. Other vital elements include establishing service level objectives and metrics for monitoring and measuring performance. These elements all warrant increased research. Section V of this report identifies three projects in this category.

Research Area 2: Risk Management

A fundamental purpose of asset management is to manage risks associated with failure, keeping risks within acceptable tolerances. Risk can be defined as the probability of failure combined with the consequences of that event. Risks are often categorized as:

- High Probability, High Consequence
- High Probability, Low Consequence
- Low Probability, High Consequence
- Low Probability, Low Consequence

For example, if a water system had a single feed that was prone to multiple breaks, and that feed served a hospital, the associated risk would be a high probability of failure coupled with high consequences. Such a condition would likely receive a high priority for mitigation.

The *International Infrastructure Management Manual* (IPWEA 2006) identifies managing risks associated with asset failures as one of seven key elements in an asset management program. The importance of using risk as a fundamental element in decision making is widely acknowledged by asset management professionals in water, wastewater, power, transportation, and other industries.

Risks must be balanced against the costs of avoiding or mitigating them. This balance comes into play in many decisions, such as when to replace a pipeline or whether to install redundant transmission mains, pumps, or power backup systems. Risk analysis can also be used to determine how much to invest in condition assessment for critical facilities. All of these areas involve uncertainty, especially for buried assets.

Based on the case studies performed for this project, staff members responsible for asset management in participating utilities recognize the central role that risk management plays in asset management. For example, American Water and Louisville Water Company identified risk as a key factor when identifying facilities for replacement.

American Water's case study indicates the following with regard to risk assessment:

> *"Renewal versus replacement of an asset is determined by a life-cycle cost analysis on a case-by-case basis. Risk is frequently an overriding factor as opposed to economic life-cycle retention when the decision for replacement is made. American Water has determined over the years that replacement is normally the best form of renewal for below-ground infrastructure. This is because the utility is often forced to renew the entire road surface even when disturbance is minimized by rehabilitation methods. Renewal of aboveground infrastructure is evaluated more closely versus replacement."*

While there are some exceptions, formal approaches to risk assessment and risk management do not appear to be widely practiced at this time. For example, many of the case study utilities had not assigned criticality ratings to their facilities, which is a fundamental practice important to sound risk management.

While risk assessment techniques are well documented and widely used in certain industries, there appears to be a need to more clearly describe and demonstrate their applicability in the water and wastewater industries. This was evident at the Research Roadmap workshop, where participants thoroughly discussed a project on risk assessment. It was suggested that analysis of risk be extended to cover the "triple bottom line" of financial, social, and environmental considerations. This would enable North American utilities to improve their capabilities to assess and manage risks in making decisions on asset maintenance, repair, rehabilitation, and replacement.

Research Area 3: Condition Assessment and Performance Monitoring

Assembling and maintaining up-to-date information on the condition and performance of infrastructure and equipment is vital to the practice of asset management. Understanding exposure to risks and assessing costs of needed investments depend heavily on this information.

At the workshop conducted for this project, participants identified several areas of interest with regard to condition assessment. They recognized that condition assessment is an important element in performing risk assessment. It was also stated by several workshop participants that significant research has been performed on condition assessment practices for numerous classes and types of assets; however, condition assessment still remains a challenge to most utilities. Few utilities felt that they had a comprehensive database of buried asset condition adequate to perform risk analysis and to make maintenance/renewal decisions.

Buried Assets. The most challenging area of condition assessment and performance monitoring involves buried assets, primarily pipes. These buried assets represent the largest infrastructure investment in water and wastewater systems (Allbee 2005). The case studies developed for this project suggest that most water utilities do not have systematic programs for assessing and documenting pipe condition. This is also borne out by previous studies (Cromwell et al. 2001, Deb, Grablutz, Hasit, Snyder, Loganathan and Agbenowski 2002). Large-diameter transmission mains are particularly problematic in this regard. Non-destructive testing techniques are typically not available or cannot be readily implemented, given the configuration of mains and communities' reliance on transmission mains that do not have redundant backups.

One of the case studies prepared for this project involved American Water, a private company with over 400 water and wastewater systems across the US. As a tool for condition monitoring, American Water has been pilot testing an innovative approach that uses continuous leak detection through a network of acoustic sensors. The system also improves data collection for analyzing and predicting failure rates in different parts of a distribution pipe network.

Some utilities reviewed for the case studies use indirect methods for monitoring the performance of buried mains and appurtenances, including flushing data and water quality information such as "rusty" or "red water". Exercising valves is another means of gathering information. Utilities use flow tests to gather information on hydraulic conditions of pipelines to estimate "C" Factors and fire fighting capability. The Louisville Water Company case study found that age of pipe is not a good predictor of condition or susceptibility to breakage. Many of the Louisville Water Company's older pipes are in better condition than newer ones.

Many utilities simply have not implemented systematic approaches to monitoring condition and performance. In the wastewater industry, television inspection of sewer pipes is widely used. This is not practical for pressurized water pipes, and direct methods of inspection are not readily available except in cases where water pipes are exposed for repairs or work on adjacent utility lines.

The White Paper prepared for this project indicates that the biggest gaps in the area of condition assessment for buried pipes appear to be in systematically collecting and organizing data and in using formal risk assessment procedures to prioritize expenditures. In addition, there is a need for improved inspection and condition evaluation technologies. Finally, effective application of condition assessment techniques requires that information be broadly disseminated throughout the industry and that utility staff receive appropriate training.

Aboveground Assets. Different tools and techniques apply to aboveground assets such as reservoirs, pump stations, and treatment plant equipment. A recent AwwaRF study developed tools for assessing the physical condition and operating characteristics of water treatment plants (Elliott et al. 2003). The Elliott assessment contributes to prioritization of components that need repair, rehabilitation, or replacement.

Condition monitoring techniques for operating equipment can include oils analysis, vibration monitoring, infrared, ultrasonic, and motor current signature analysis (Fortin et al. N.d.). While these procedures are well developed, they are not widely used in the water and wastewater industries at this time, although their adoption rate is increasing.

The case study describing the program for condition assessment at the Los Angeles Department of Water and Power (LADWP) illustrates how different aboveground system components may be addressed:

- LADWP operates approximately 80 pumping stations. These pumping stations were prioritized by criticality and condition and scheduled for inspection. Rehabilitation or replacement projects have been scheduled for the 10 highest priority pumping stations.
- LADWP operates approximately 370 pressure regulating stations. A dedicated repair and retrofit crew is visiting these regulating stations in order of priority and performing necessary work.
- The LADWP distribution system includes both concrete and steel potable water reservoirs. On average, each reservoir is inspected once every 3 years. LADWP renews the coating on two to four steel reservoirs each year.

It should be noted that LADWP's program for condition assessment appears to be more systematic than that of most utilities in North America.

In the readiness review for Cleveland Water, it was noted that the utility had a mature and comprehensive inspection and condition assessment program for its water treatment plants and primary pump stations. The comprehensive inspection program was a proactive initiative to identify failing or problem infrastructure at these facilities. From 1997 to 1999, Cleveland Water developed a series of Project Development Reports based on the condition assessments. Projects were identified, prioritized, funded, and implemented to make the improvements. In addition to the comprehensive inspections noted, Cleveland Water has a system for ongoing, routine surveillance of aboveground facilities.

Projects Carried Forward to Research Roadmap. Workshop participants identified a specific need for improved techniques to assess the condition of pre-stressed concrete cylinder pipe (PCCP). Participants recommended that further information be gathered on condition assessment for water main appurtenances such as hydrants, valves, pressure-reducing valves, air-release valves, blow-offs, and service lines. These ideas have been carried forward and refined into project descriptions (Appendix D).

Research Area 4: Decision Making for Capital Improvement Programs (CIP) and Replacement and Renewal (R&R)

An effective asset management program produces sound, well-documented decisions on capital investments. These investments may include creation of new assets; repair, rehabilitation, and replacement of existing assets; and decommissioning and disposal of assets that reach the end of their useful lives. Most of the policies, strategies, and practices within asset management are designed to enable or improve capital asset investment decision making. Therefore, the topics discussed in this section all contribute to this key initiative.

As described in the White Paper (Appendix A), the decision making process for capital projects should ideally include a number of attributes, such as:

- Analysis of the full life-cycle cost of assets that are created, acquired, rehabilitated, or repaired;
- Application of systematic cost-benefit analysis;
- Incorporation of risk management considerations;

- Consideration of "triple bottom line" effects (i.e., financial, social, and environmental), if consistent with utility goals;
- Ability to compare different investments, both within asset classes and across asset classes; and
- Recognition of how current decisions affect long-term performance and financial needs in the future, many times over multiple generations.

To understand these attributes, a decision maker needs data on costs, risks, condition, and other aspects of the assets under consideration. Planning models or predictive models of asset failure may be developed.

As previously mentioned, the largest single asset class in terms of value for most water utilities is buried mains and appurtenances. One of the key areas of capital decision making, therefore, is whether to repair, rehabilitate, or replace water mains. Decisions about water mains should be made using many types of information including condition and performance, failure rate of similar mains in the system, coordination with construction projects involving roads or other utility lines, and other factors.

In this context, understanding failure trends for different classes of water mains in a given utility's distribution system can be very useful. Systematic collection and analysis of utility-specific data on main breaks is one technique that can be used to understand failure trends. Data collection provides the opportunity to analyze trends, identify physical characteristics that correlate with breakage, and identify spatial patterns within the pipeline network. However, pipe break data is not collected systematically at most utilities. In addition, predictive models utilizing break data to guide decisions on pipe rehabilitation and replacement are not well developed in the water and wastewater industries (Cromwell et al. 2001).

The case study on Louisville Water Company's Main Replacement and Rehabilitation Program describes a model program with well-documented results. Louisville Water Company established its program in 1992. The driver for this program was an identified need to replace 500 miles of aging, unlined cast iron mains installed prior to 1937. Program elements include:

- Collection of main break data;
- A Pipe Evaluation Model incorporating 23 criteria such as location, soils age, paving age, hydraulic characteristics, maintenance record and main breaks, and record of water quality problems;
- A robust geographic information system (GIS) that stores data on the entire distribution system;
- A utility coordination program to ensure that main replacement and rehabilitation projects are coordinated with road, street, and other utility projects; and
- A risk management program linked to key objectives in the utility's strategic plan.

Louisville Water Company has used rates to fund much of the program, enabling replacement of 1 to 1.5 percent of the distribution system each year without taking on additional debt. The utility has reduced main breaks by 140 breaks per year, representing a 20-percent reduction since 1992.

Based on the workshop results, two projects were defined that address improving the understanding of degradation and failure of utility assets. Degradation rates and expected lifetimes of buried assets are not well defined at this time for the many diverse conditions utilities face in the field. Improved information is needed so utilities can better plan maintenance, repair, and rehabilitation programs. Similar decisions must be made regarding equipment at wells, pump stations, reservoirs, and other aboveground facilities; therefore, a similar research project is proposed for aboveground assets.

A central database is contemplated to collect data on main breaks throughout North America. When analyzing risk or when making replacement and renewal decisions, utilities could access the database and draw conclusions based on failure data for similar pipe types or similar conditions. It is interesting to note that the United Kingdom, through UKWIR, maintains such a database for its members. Also, at a workshop sponsored by the US Environmental Protection Agency (USEPA) in 2005 (USEPA 2005), the participants recommended development of a central repository of high-quality data that would be available to researchers. Thus, substantial support exists for the idea of establishing a central repository of data.

Research Area 5: Asset Management Information Technology (IT) and Data Management

Managing assets effectively relies upon accurate and up-to-date information. Information is needed on the assets themselves, their location, condition, performance, maintenance cost, and maintenance history. Key performance indicators (KPIs) used to track performance outcomes also require accurate and timely information. Developing, maintaining, and managing data systems are critical elements of effective asset management programs.

For data systems to be effective, the utility must have a clear strategy for how they will be used. With this strategy in hand, it is also important to develop data standards, a quality assurance/quality control program for data, and a clear and well-communicated structure for data flow within the organization. Finally, to answer key questions about system assets and the asset management program, tools must be available that enable access to data stored in different systems and data integration.

The US General Accounting Office (USGAO) found that collecting and managing data are key challenges for implementing asset management. Data currently held by utilities are often incomplete, outdated, or inaccurate. This problem is compounded by the fact that data needed for comprehensive asset management are typically stored in multiple databases, hampering coordination across departments or utility functions (USGAO 2004). Case studies performed for this project demonstrated that data formats and even nomenclature for specific assets may differ within a utility organization. These problems are also experienced in other industries.

A variety of data management systems are used by utilities. For asset management purposes, the most important of these systems are financial and enterprise data management systems, GIS, and computerized maintenance management systems (CMMS). Upgrading systems or making significant modifications in how they are used can be highly challenging and expensive, especially considering costs already invested in existing data management structures.

The asset management readiness reviews conducted as part of this project evaluated IT and data management issues in detail. For Denver Water, the readiness review found that the utility tracks asset data in several asset databases. The primary asset databases include the JD Edwards financial system, the ESRI GIS, and the Maximo CMMS. These systems have all of the features required to support management of the utility's asset data. In addition, several secondary asset databases have been propagated and are utilized by specialized groups within Denver Water for specific purposes. While each asset database has a detailed asset naming/asset numbering system, there is not a formal asset naming convention used by all systems. This makes it somewhat difficult to compare, reconcile, or share data among the asset databases.

There is a structured process to enter asset data from new projects into the existing asset databases. This ensures that assets installed as part of new projects are tracked. However, there is no formal process in place to update the asset databases when an asset is rehabilitated to extend the asset's life, replaced, moved, or taken out of service, unless a specific capital accounting work order is created and is tagged to a specific asset. Overall, the asset databases seem relatively complete within the boundaries of the utility's combined service area. The utility's program for tracking asset data is significantly ahead of that used by many North American water and wastewater utilities.

Cleveland Water also has several databases to track existing assets, including the following: a CMMS to store a registry of some assets including pumping equipment, treatment plant equipment, and large-diameter pipe; an ESRI GIS that is being implemented to track distributed assets (pipes, valves, hydrants, etc.); an AS 400-based legacy billing system; a custom legacy system for the fleet assets; and a PeopleSoft-based asset registry to generate financial reports. While each database has a detailed asset naming/asset numbering convention, there is no formal asset naming convention that is used by all systems, making it difficult to compare, reconcile, or share data between asset databases.

Another asset management readiness review conducted for Tacoma Water illustrates the use of an integrated information system. In 2003, Tacoma Water launched a new enterprise information system using SAP® software. Implementing this system is part of a city-wide effort that extends beyond the water utility. The system is used to track assets, to plan and dispatch maintenance work, and to collect and analyze asset data. The same system handles financial management, billing, and human resources functions. Due to considerable investment of staff and management time in planning and building the system, it is successful for managing across multiple functions.

Implementing the new system in Tacoma and taking advantage of available functionality is an ongoing process. Current challenges include the following:

- Incorporating criticality descriptors in the SAP® system to allow for structured prioritization of inspection programs and capital projects, thereby directing resources to manage higher-risk needs.
- Developing a data collection and utilization plan for the system's data warehouse.
- Developing KPIs that access real-time data from the system to support management of key functions.
- Adding assets into the system that were not initially included, and adding maintenance work plans to the system for assets that do not yet have them.

The workshop identified three projects as priorities for research (two of these were subsequently combined into a single project): information system integration, data modeling, and data management for asset management. Thus, all of the highly rated IT and data management related projects from the workshop were carried forward and refined into recommended projects.

Research Area 6: Operation and Maintenance Practices

Operation and maintenance (O&M) practices affect the condition, performance, and longevity of system assets and are therefore vital to asset management. In addition, managing life-cycle cost is one of the key objectives of asset management. The annual cost of operating and maintaining assets can be a major component of life-cycle cost, especially for equipment at pump stations and treatment plants.

Key aspects of O&M pertaining to asset management include the following (Fortin et al. N.d.):

- A well-planned maintenance strategy that takes into account risk factors and criticality of various system components to optimize the maintenance program. Such a system should balance preventive maintenance and reactive maintenance, according to this strategy.
- A system for scheduling, issuing, and tracking work orders. For mid-size to large utilities, the use of a CMMS can increase productivity and provide timely access to asset data.
- Condition and performance monitoring, with linkage to maintenance activity.
- Attention to metrics of maintenance work efficiency.
- Materials management and purchasing.

The District of Columbia Water and Sewer Authority (DCWASA) has seen the benefits of an organized distribution system maintenance program. The case study indicates the following:

- As a result of the flushing and valve cycle operations programs, fewer valves need replacement because they are being operated more. Since the valve cycle operations program was established, DCWASA has been able to reduce preventive maintenance frequency from every 12 months to every 18 to 24 months.
- DCWASA's recently-installed fixed network Automated Meter Reading (AMR) system enables detection of customers' potential water leaks. DCWASA uses this functionality to notify customers of possible leaks and water wastage as soon as the problems are detected. This has contributed to a 30-percent reduction in call monitoring for metering issues.

Based on the findings described in the White Paper and most case studies prepared for this project, there is considerable room for North American utilities to improve O&M practices. For example, few utilities develop deliberate maintenance strategies that balance preventive maintenance with reactive maintenance using risk- and cost-based guidelines. At many utilities, maintenance history is not tracked in a manner that supports cost analysis and decision making on asset repair, rehabilitation, and replacement.

Workshop participants ranked development of best practices for maintenance of distribution system assets highest among all the research projects considered; the distribution system is a utility's largest capital investment. Proper maintenance would extend asset lifetimes and enhance operational characteristics. Currently, utilities rely on numerous sources of information and past practices to plan and carry out their maintenance programs. There is a need to review and consolidate practices into a single resource to facilitate effective maintenance programs, improve utilities' ability to manage maintenance costs, and strengthen linkages between maintenance and capital planning.

CHAPTER 3
RESEARCH ROADMAP AND IMPLEMENTATION STRATEGIES

RESEARCH AREAS AND ROADMAP PROJECTS

The Research Roadmap projects and prioritization were initially developed through the workshop described in Section II and Appendix B. The team subsequently refined the Research Roadmap to avoid duplication of effort and to reflect ongoing research that is already being funded by AwwaRF or other organizations. The recommended Research Roadmap is based on the six research areas (listed below) in the Asset Management Research Framework and Findings presented in Section IV.

Research Area 1: Asset Management Framework/Models for Organizations
Research Area 2: Risk Management
Research Area 3: Condition Assessment and Performance Monitoring
Research Area 4: Decision Making for CIP and Replacement and Renewal (R&R)
Research Area 5: Asset Management IT and Data Management
Research Area 6: Operation and Maintenance Practices

As a first step in developing and implementing this Research Roadmap, this report includes the information listed below.

1. The proposed research projects under each of the six research areas are summarized in Figure 3.1. Figure 3.1 shows how the projects fit together in an organized, sequential fashion with anticipated costs and a proposed timeline.
2. Further details of the objectives, key elements, and benefits for each proposed project are listed in Tables 3.1 through 3.7
3. Individual project descriptions that contain more project details are included in Appendix D.

The Project Advisory Committee provided guidance on what it believes to be the highest priority AM projects for consideration by the Research Advisory Council and the AwwaRF Board of Trustees, as follows:

Research Area	**Project**
Asset Management Framework/Models for Organizations	1.3 Prepare Guidance Manual on Level of Service and Metrics
Decision Making for CIP and R&R	4.3 Central Repository of Asset Data to Support Maintenance, Repair, Rehabilitation, and Replacement for Water Mains
AM IT and Data Management	5.1 IT Integration and Data Model to Support AM
Operation and Maintenance Practices	6.1 Guidance Documents for Best Maintenance Practices for Water Distribution Assets

The thought was that these four projects would advance AM principles and acceptance by the water utility industry and that these projects would lay the groundwork for future research as well. Ratings for other projects are presented in Figure 3.1.

ONGOING AND PLANNED RESEARCH AND TRAINING EFFORTS

Implementation efforts for this Research Roadmap will need to coordinate with the many ongoing and planned research and training efforts that are being conducted by AwwaRF and other entities. Some of these efforts are summarized below.

The USEPA Office of Research and Development has been allocated $7 million per year from 2007 through 2011 to support a new research program. The program will support the science and engineering efforts required to improve and evaluate promising innovative technologies and techniques. These technologies and techniques will reduce the cost and improve the effectiveness of operation, maintenance, and replacement of aging and failing drinking water and wastewater treatment and conveyance systems. Of that $7 million, it is estimated that $2 million per year will be allotted to drinking water (total for 5 years will be $10 million). The areas of emphasis may be on condition assessment of water distribution systems, system rehabilitation, and advanced concepts for drinking water distribution systems. This USEPA program is in early development, and AwwaRF will want to monitor its progress and collaborate, where possible.

There are several ongoing AwwaRF projects that can be used as a basis for selecting projects and tailoring the project descriptions contained in Appendix D as they are developed into Requests for Proposals. Some of the ongoing AwwaRF projects along with their status are listed in Table 3.9.

The WERF Board of Trustees has approved $1.6 million for a Strategic Asset Management Challenge (#06-SAM-1CO) that will occur from 2007 to 2010, subject to federal funding. Some of the planned topics include stakeholder communications, benchmarking and case studies, decision support tools and implementation guidance, and prediction of remaining asset life.

With grants from the National Science Foundation (NSF) and others, Pennsylvania State University and Virginia Polytechnic Institute & State University is conducting research investigations into municipal infrastructure asset management. Some of this work is oriented toward drinking water, including the following: a Web site primer funded by USEPA; a project named Sustainable Water Infrastructure Management System (SWIMS) funded by NSF that will feature a GIS-based, Web-based pipeline information and visualization system; and use of a supercomputer to analyze asset management data (NSF 2007).

NRC Center for Sustainable Infrastructure Research (CSIR) has opened a fully-staffed office and laboratory space in Regina, Saskatchewan. Its initial projects include addressing performance of water mains, life-cycle costing, and risk-based decision models.

As indicated by the brief descriptions above, there are numerous agencies studying and evaluating municipal assets. Some agencies are dealing with training, while others are focusing on research or implementation. The softer-side work, e.g., management and organizational efforts, is applicable to both water and wastewater entities. However, there appears to be more research effort focused on wastewater conveyance than on drinking water distribution, and much of that work is not transferable because of the unique attributes of drinking water transmission and distribution systems. To reduce the potential for duplication and to leverage efforts, where feasible, AwwaRF will need to continue its careful review of the efforts of other entities.

Research Areas and Projects

Research Areas and Projects	Year 1	Year 2	Year 3	Year 4	Year 5	Project Value	Duration (Months)	PAC Rating
	Schedule, Duration, and Funding							
Research Area 1: Asset Management Framework/Models for Organizations								
1.1) Policies and Strategies to Implement Asset Management (AM) Programs						$350,000	30	Medium
1.2) Organizational Characteristics of Effective Asset Management Programs						$300,000	24	Medium
1.3) Prepare Guidance Manual on Level of Service and Metrics						$300,000	24	High
Research Area 2: Risk Management								
2.1) Risk Management Protocols Supporting Capital Investment Decisions						$400,000	30	Low
Research Area 3: Condition Assessment and Performance Monitoring								
3.1) Workshop and Synthesis Document on Condition Assessment of Pre-stressed Concrete Cylinder Pipe						$150,000	18	Medium
3.2) Develop Guidance Manual for Condition Assessment of Water Main Appurtenances						$350,000	30	Medium
Research Area 4: Decision Making for CIP and R&R								
4.1) Develop and Validate Degradation Curves for Buried Water Distribution System Assets						$350,000	36	Low
4.2) Develop and Validate Degradation Curves for Aboveground Water Distribution System Assets						$350,000	36	Low
4.3) Central Repository of Asset Data to Support Maintenance, Repair, Rehabilitation, and Replacement for Water Mains						$100,000	12	High
Research Area 5: AM IT and Data Management								
5.1) IT Integration and Data Model to Support AM						$550,000	42	High
5.2) Evaluate Strategies for Data Creation, Collection, Validation, and Maintenance for AM including an Asset Data Dictionary						$550,000	48	Low
Research Area 6: Operation and Maintenance Practices								
6.1) Guidance Document for Best Maintenance Practices for Water Distribution Assets						$400,000	30	High

Note: PAC – Project Advisory Committee

Figure 3.1 Research Roadmap Schedule and Budget

Table 3.1
Research Area 1: Asset Management Framework/Models for Organizations

Research Area and Projects	Objectives and Key Elements	Benefits
1.1) Policies and Strategies to Implement Asset Management (AM) Programs (Coordinate with Roadmap Research Area 5, Project 5.1: IT Integration and Data Model to Support AM)	• Develop a conceptual framework specific to North American water utilities for implementing and managing an asset management program. • Identify policies required to support asset management (e.g., financial/rates, life-cycle costing, triple bottom line, condition-based, etc.). • Develop a guidance document for implementing an asset management program. • Build on the strategy guidelines articulated in *Implementing Asset Management: A Practical Guide* (AMSA et al. 2007).	• Establishes a conceptual framework for application of asset management policies and strategies that is scalable to water utilities of various sizes. • Identifies policy priorities for building and maintaining an asset management program. • Provides guidance on how a utility establishes an asset management program.
1.2) Organizational Attributes of Effective Asset Management Programs	• Identify organization characteristics and models that support effective AM programs. • Define organizational elements required for successful AM program implementation. • Address required skills and organizational capabilities. • Develop strategies to integrate asset management practices into an organization, including change management. • Produce an implementation guidance manual including tools and techniques to assess organization readiness, identify skill gaps, and develop change management strategies.	• Saves time and effort of individual utilities conducting redundant research on various organizational models. • Establishes a set of asset management organization models, characteristics, and elements for use by utilities along with an implementation guidance manual. • Proven organization models will improve the adoption rate of asset management policies and best management practices.
1.3) Prepare Guidance Manual on Level of Service and Metrics	• Determine standard level-of-service metrics and key performance indicators (KPIs) to meet customer, environmental, financial, and stakeholder expectations related to asset management. • Develop guidance and implementation strategies. • Identify the role of information systems in accurate, reliable, and timely reporting. • Determine applicability and transferability of various level-of-service methodologies used in other industries. • Build on AwwaRF's *Selection and Definition of Performance Indicators for Water and Wastewater* (Crotty 2003). • Prepare a guidance document with methodologies and practices to implement level-of-service metrics and KPIs.	• Sets standard metrics and KPIs that lead to positive changes in service levels. • Guides utilities on the purpose and value of service-level agreements. • Improves decision making related to capital asset investments. • Supports service-level benchmarking across utilities and other industries.

Table 3.2
Research Area 2: Risk Management

Research Area and Projects	Objectives and Key Elements	Benefits
2.1) Risk Management Protocols Supporting Capital Investment Decisions	• Identify categories of risk encountered in asset management decision making, including financial, social, and environmental risks (triple bottom line). • Review techniques for assigning values to risk in a cost-benefit framework. • Explore mitigation techniques for different risk categories. • Develop risk management framework for managers to make effective asset management decisions. • Beta test the framework/methodology in three participating utilities. • Build on the findings of AwwaRF reports and ongoing projects: *Triple Bottom Line Reporting of Sustainable Water Utility Performance* (Kenway et al. 2007), "Tool for Risk Management of Water Utility Assets" (UKWIR In Progress (a)), and "Tool for Benefit Cost Analysis" (WERF In Progress).	• Reduces risk profile for utility. • Helps avoid adverse impacts to customers, communities, and environment. • Improves efficiency in use of capital (long term). • Potentially improves bond ratings. • Improves environmental sustainability.

Table 3.3
Research Area 3: Condition Assessment and Performance Monitoring

Research Area and Projects	Objectives and Key Elements	Benefits
3.1) Workshop and Synthesis Document on Condition Assessment of Pre-stressed Concrete Cylinder Pipe (PCCP). (Project should be coordinated with Bureau of Reclamation and may be considered for a Tailored Collaboration Project.)	• Conduct workshop to assess the effectiveness of the latest condition assessment techniques for PCCP. • Present case studies as part of workshop. • Develop synthesis document from workshop and participating utilities focusing on the current state of PCCP condition assessment and performance monitoring. • Build on the findings of AwwaRF reports and ongoing projects: *Workshop on Condition Assessment Inspection Devices for Water Transmission Mains* (Lillie et al. 2004), *Electromagnetic Inspection of Pre-stressed Concrete Pressure Pipe* (Mergelas and Kong 2001), and failure of Pre-Stressed Concrete Cylinder Pipe" (Boyle Engineering Corp. In Progress).	• Utilities and stakeholders can share information and get the latest technical information on PCCP. • Synthesis document will consolidate key findings for ready use by industry. • Will identify gaps in knowledge and tools that can be used as basis for planning future needs and research.
3.2) Develop Guidance Manual for Condition Assessment of Water Main Appurtenances. (Coordinate with Roadmap Research Area 6, Project 6.1: Guidance Document for Best Maintenance Practices for Water Distribution Assets.)	• Provide for uniform classification system of appurtenances (hydrants, valves, pressure-reducing valves, service lines, air-release valves, blow-offs, etc.). • Summarize or develop performance criteria for water main appurtenances. • Consolidate condition assessment information from previous efforts and develop guidance manual. • Build on numerous AwwaRF projects including: *Installation, Condition Assessment, and Reliability of Service Lines* (Le Gouellec and Cornwell 2007); *Potential Techniques for the Assessment of Joints in Water Distribution Pipelines* (Reed et al. 2006); *Key Criteria for Valve Operation and Maintenance* (Rosenthal et al. 2002); *Performance and Life Expectancy of Elastomeric Components in Contact With Potable Water* (Rockaway et al. 2007); *Condition Assessment Strategies and Protocols for Water and Wastewater Utility Assets* (Marlow et al. 2007); and *Criteria for Optimized Systems* (HDR Engineering, Inc. In Progress (b)).	• Improve consistency in use of criteria and methods of condition assessment for appurtenances. • Assist utilities with developing appropriate maintenance plans. • Help ensure compliance with International Standards Organization (ISO). • Provide consistent criteria for benchmarking. • Provide a uniform method for classifying appurtenances.

Table 3.4
Research Area 4: Decision Making for CIP and R&R

Research Area and Projects	Objectives and Key Elements	Benefits
4.1) Develop and Validate Degradation Curves for Buried Water Distribution System Assets	• Determine factors that influence deterioration to categorize assets and associated degradation curves. • Identify and summarize factors that cause underground water distribution system assets to fail (e.g., inadequate bedding, vibration, traffic, hydraulic surges, etc.). • Gather information on lifespan of selected asset classes. Prepare decay curves based on failure causes or other factors. • Present knowledge base in the form of decay curves with validation information. • Coordinate with ongoing and planned work from WEF and AWWA Standards Committee.	• Enables utilities to more accurately estimate performance, degradation, and failure. • Improves estimates of remaining service life. • Optimizes rate-of-return from investments in repair, rehabilitation, and replacement. • Reduces risk of catastrophic failure. • Assists vendors in developing improved manufacturing processes for buried assets.
4.2) Develop and Validate Degradation Curves for Aboveground Water Distribution System Assets	• Determine factors that influence deterioration to categorize assets and associated degradation curves. • Identify and summarize factors that cause aboveground water distribution system assets to fail (e.g., vibration, hydraulic surges, vandalism, being struck by motor vehicles, overheating, freezing, etc.). • Gather information on lifespan of selected asset classes. Prepare decay curves based on failure causes or other factors. • Present knowledge base in the form of decay curves with validation information. • Coordinate with ongoing and planned work from WEF and AWWA Standards Committees.	• Enables utilities to more accurately estimate performance, degradation, and failure. • Improves estimates of remaining service life. • Optimizes rate-of-return from investments in repair, rehabilitation, and replacement. • Reduces risk of catastrophic failure. • Assists vendors in developing improved manufacturing processes for aboveground assets.
4.3) Central Repository of Asset Data to Support Maintenance, Repair, Rehabilitation, and Replacement (MRRR) for Water Mains	• Assess the feasibility and industry demand for a central repository to collect and trend water main failure data for use by utilities in determining their future MRRR spending. • Develop alternative delivery, management, and financial models to support ongoing data collection and management services for central repository. • Evaluate relevancy and applicability of the National Breaks Database concept such as UKWIR's National Mains Failures Database (Hale et al. 2006).	• Provides central database of water main failure data for use by subscribing entities. • Assists utilities in establishing MRRR programs and CIP and justifying programs and expenditures to boards and customers. • Initiates process to establish industry standards for MRRR decisions, ultimately leading to benchmarking metrics.

Table 3.5
Research Area 5: Asset Management IT and Data Management

Research Area and Projects	Objectives and Key Elements	Benefits
5.1) IT Integration and Data Model to Support AM. (Coordinate with Roadmap Research Area 1, Project 1.1: Policies and Strategies to Implement Asset Management (AM) Programs.)	• Define the role of Information Technology (IT) in AM business process management. • Identify systems integration approaches that demonstrate how component asset management systems can be integrated. • Establish a conceptual and logical data model for AM. • Refine the integration approach and data model through pilot implementations at three utilities (tailored collaboration). • Coordinate with project "Optimizing Information Technology Solutions for Water Utilities" (Red Oak Consulting In Progress).	• Sets guidelines to assist utilities in understanding alternatives and applicability when determining a "best fit" solution for IT integration. • Supports improved asset management decision making and reporting through the use of data sets and models proven to work in operating utilities. • Provides industry-standard integration and data model for use by vendors in software and product development. Over time, this will drive vendors to enable better integration and potential inter-operability of component asset management systems.
5.2) Evaluate Strategies for Data Creation, Collection, Validation, and Maintenance for Asset Management including an Asset Data Dictionary	• Identify Best Management Practices for data management as they relate to asset data management. • Formulate data management procedures for North American water/wastewater utilities. • Formulate guidelines for implementing data management procedures, practices, and technologies. • Create industry-standard, data dictionary templates for buried and aboveground assets. • Conduct a pilot test to apply data management and data dictionary procedures at participating utilities. • Coordinate with details of condition assessment data in "Data Requirements for Water Infrastructure Management" (AwwaRF In Progress) and "Optimizing Information Technology Solutions for Water Utilities" (Red Oak Consulting In Progress); and the 5 year NSF grant to Virginia Tech to create "Sustainable Water Infrastructure Management System (SWIMS)" (NSF 2007).	• Improves data access, consistency, and accuracy for asset management decision making and strategies. • Provides data standards that meet regulatory, traceability, audit, and security requirements. • Enables utilities to better determine what data to collect and how to use the data to support asset management. • Increases confidence in asset management decision making and reporting to regulatory and funding agencies.

Table 3.6
Research Area 6: Operation and Maintenance Practices

Research Area and Projects	Objectives and Key Elements	Benefits
6.1) Guidance Document for Best Maintenance Practices for Water Distribution Assets. (Coordinate with Roadmap Research Area 3, Project 3.2: Develop Guidance Manual for Condition Assessment of Water Main Appurtenances.)	• Consolidate information and provide guidance on Best Maintenance Practices for distribution system assets. • Develop preventive, predictive, and corrective maintenance practices for water distribution assets (i.e., pipes, valves, pumps, and finished water reservoirs, but not treatment plants). • Explore how maintenance practices relate to risk, criticality, life-cycle costs, condition assessment, and related aspects of asset management. • Coordinate with AwwaRF work: "Criteria for Optimized Distribution Systems" (HDR Engineering, Inc. In Progress (b)), and *Applicability of Reliability-Centered Maintenance in the Water Industry* (Basson et al. 2006.) • Coordinate with materials from Water Services Association of Australia (mechanical, electrical, etc.) and with AWWA Qual Serve Practices.	• Provides single location/resource for use by utilities where maintenance information has been consolidated and synthesized. • Enables utilities' access to an independent source of best practices for maintenance of distribution assets. • Provides clear linkage between maintenance and capital planning elements of asset management programs. • Improves reliability, efficiency, productivity, cost-effectiveness, and service to customers. • Contributes to cost containment by applying maintenance planning and cost-effective practices within a life-cycle asset framework.

Table 3.7
Ongoing AwwaRF Projects (Including Collaboration Efforts)

AwwaRF #	Project Name	Brief Description	Lead Organization	Co-funders	Status
3048	Condition Assessment Strategies and Protocols for Water and Wastewater Utility Assets	Document the broad range of available asset assessment tools and techniques, and provide guidance on how to incorporate condition assessment strategies into a utility's asset management philosophy. This report also provides descriptions and reviews of 84 individual condition assessment tools and techniques used in the water and wastewater industries, including a discussion of principles, applications, practical considerations, advantages, and limitations. (Marlow et al. 2007)	WERF	AwwaRF, US USEPA, CSIRO	To be published electronically in Fall 2007.
4013	Sustainable Infrastructure Management Planning and Learning Environment (SIMPLE) Version 1.1	Will modify the existing wastewater-specific asset management website SIMPLE launched by WERF, with drinking water content to create SIMPLE, version 1.1. SIMPLE, Sustainable Infrastructure Management Planning and Learning Environment, is a guidance manual, with limited user interaction via the chat room and a question and answer section. Over time, more interactive tools may be added. (GHD In Progress)	WERF	USEPA and AwwaRF	The final product is not a report, but the actual Web site. The Web site (version 1.1) will go live in 1st quarter of 2008.
4085	Setting Water Utility Investment Priorities: Assessing Customer Preferences and Willingness to Pay	Will develop more robust tools to better characterize customer input to utility investment priorities. Will review survey approaches for eliciting accurate customer preferences, will describe how such tools have been used in public decision making, and will test the tools in water utility customer surveys. Also will develop a handbook that provides guidance to utilities and their vendors on designing, implementing, and analyzing customized "willingness to invest" surveys for typical utility investments. (University of New Mexico In Progress)	AwwaRF	Not Applicable	Planned completion in 2010.
4108	Data Requirements for Water Infrastructure Management	Will define data elements required for condition assessment of buried assets for a number of expected management approaches. Will create and test a standardized framework for data structure. (AwwaRF In Progress)	AwwaRF	GWRC: WERF	Ongoing scope development.

(Continued)

Table 3.7 (Continued)

AwwaRF #	Project Name	Brief Description	Lead Organization	Co-funders	Status
4111	Case Studies of Best Practice and Innovation in Asset Management	Will develop five short case studies of North American drinking water utilities that exhibit best practices or innovation in asset management. Each participating organization will contribute case studies to create a final "Compendium of Best Practice and Innovation in Asset Management." (HDR Engineering, Inc. In Progress (a))	WRc will compile case studies from each GWRC participant.	GWRC: AwwaRF, UKWIR, WERF, WSAA	AwwaRF case studies to be completed 2007. GWRC Compendium to be published in 2008.
4126	Tool for Risk Management of Water Utility Assets	Will develop a framework to enable water utilities to adopt a common understanding and common principles in risk management of their assets, conforming with relevant international standards and best practices and allowing risks to be compared and prioritized between utilities and other organizations. Will devise an approach, adaptable to individual circumstances, for water utilities to assess and manage the risk of their assets, covering cost, decision models, strategic security, the role of expert judgment, and the impact of asset standards on performance (including environmental), customer service, and investment requirements. (UKWIR In Progress (a))	UKWIR	GWRC: AwwaRF, WERF, WSAA	To be published 2008, second quarter.
4127	Methodology for Cost and Benefit Valuation in Asset Management Decision Support	Will develop an electronic-based methodology to balance maximal service performance of assets with minimal cost of ownership. Will evaluate benefits, compare direct and indirect costs, determine present value, allow for triple bottom line accounting, and value risks for failure. Research Partner: GWRC. (WERF In Progress)	WERF	GWRC: AwwaRF, UKWIR	To be published 2008, third quarter.

(Continued)

Table 3.7 (Continued)

AwwaRF #	Project Name	Brief Description	Lead Organization	Co-funders	Status*
4034	Failure of Pre-Stressed Concrete Cylindrical Pipe	Will develop a general evaluation matrix to help utilities identify pre-stressed concrete cylinder pipe (PCCP) with the highest risk of failure in their systems. Will also provide an understanding of the trends of the number of failures and failure rate of PCCP in North America over the past 20 years. (Boyle Engineering Corp. In Progress)	AwwaRF	USEPA	To be published 2008, first quarter.
4097	Optimizing Information Technology Solutions for Water Utilities	Will identify the drinking water industry's highest priority IT needs and create a roadmap for research to meet those needs. Will also identify the types of IT products and services most needed in the industry. Will review the current state of IT in the drinking water industry, followed by a workshop at which IT experts and managers representing all functional areas within water utilities will identify current and emerging issues on areas that would be strengthened by research, and develop a prioritized, proactive research agenda. (Red Oak Consulting In Progress)	AwwaRF		Planned completion in 2010.

IMPLEMENTATION STRATEGIES

Due to the far-reaching yet integrated nature of asset management, the research initiatives are not all standalone projects; many build upon one another from the policy and framework to the tools, technologies, and practices. Thus, the following strategies should be considered in managing and implementing this Research Roadmap.

Program Management and Project Coordination

Projects identified in the Research Roadmap must be managed based on their interdependencies, on their relationships with other research in the industry, and on the integrated value of complementary research. Optimally, asset management research should be managed in a programmatic manner to attain the greatest value and return on investment, to ensure consistency among research projects, and to sustain commitment to a set of related projects. The projects in this program will be submitted to the AwwaRF Research Advisory Council's (RAC's) annual evaluation and rating process, along with dozens of other projects. As such, there is no guarantee under the RAC process that the Research Roadmap projects will receive funding or be conducted in the sequential manner recommended in this Research Roadmap. Because of the importance and widespread need for asset management in the utility industry, AwwaRF and its Board of Trustees may want to consider establishing a strategic initiative for asset management in which a pre-set amount of funding is earmarked annually for a predetermined period (e.g., 5 years to implement this Research Roadmap). The need is great, the benefits are large, and a comprehensive, long-term approach is justified.

As a minimum, AwwaRF should manage the research initiatives as a program, updating the priority of the initiatives annually and revisiting the need for new or changed research as more research is developed by AwwaRF and the many other entities performing AM research for water and wastewater. AwwaRF will need to plan for adequate staff or contractor time to manage and coordinate all of the activities in this program.

Research-Based Research Framework

The Research Roadmap is built on a flexible, research area framework that supports ongoing and future research needs. The Research Roadmap should be managed as a living program that may change and be adjusted as the six research areas move forward and individual projects are completed. This flexible approach is needed based on the changing and evolving state-of-the-art in asset management, as well as on utility acceptance and implementation of asset management principles. Annual plan updates should address changing priorities or the need for additional research in future years.

Coordination with other Research

The Research Roadmap's development acknowledges ongoing, planned, and potential future research by AwwaRF, utilities, and other agencies such as WERF, NACWA, AWWA, AMWA, GWRC, USEPA, UKWIR, NRC-Canada, WSAA, NSF, and Kiwa. AwwaRF should maintain ongoing dialog and partnerships with these entities to coordinate efforts and maximize return on research dollars over the Research Roadmap's lifespan and beyond. As indicated by the list of international agencies involved in asset management research and practices, North

American utilities have much to learn, leverage, and share with counterparts around the world. As research is conducted, findings must be consolidated and communicated across these organizations to ensure that information is readily available and usable. AwwaRF needs to have an active, dedicated role in participating in and coordinating among various research initiatives.

Prove and Evolve Research Outcomes

Many of the asset management research projects will develop tools, methods, models, and technologies that utilities can put to use in implementing asset management programs. To prove these models and to support their development over time, two key strategies should be implemented, as described below.

Prove Research through Pilot Testing

The use of pilot implementations and testing in actual operating utilities is recommended in several instances. Pilot projects help validate and refine the research in real-world applications, and provide demonstration sites for other utilities to evaluate when considering similar implementations. The use of tailored collaborations should be encouraged.

Evolve Research Outcomes

Many of the research outcomes will provide the greatest value if they are further developed and maintained through utility work groups and lessons learned from utility use. Research teams and AwwaRF should identify potential work groups and sponsoring agencies who will take responsibility for the ongoing evolution of specific research outcomes such as data models, central repository, metrics, frameworks, organization models, etc.

KNOWLEDGE CAPTURE AND INFORMATION SHARING

Asset management research will produce numerous outputs: tools, methods, guidance manuals, data analysis, models, practices, and case studies. AwwaRF will need to consider the means and methods to make this information available to members and to maintain it as “ever green.” One strategy is the use of Web portals and repositories such as SIMPLE and the central data repository (Project 4.3) contemplated within this Research Roadmap. These systems will facilitate the capture and sharing of materials, tools and research, as well as practical lessons learned by utilities in applying the research. The vision is for this research to promote the development of a practical, “go-to” resource library and data service that is supported by the user community and utilities.

CONCLUSION

The projects described in this Research Roadmap are intended for consideration by AwwaRF’s staff, Research Advisory Council, and Board of Trustees. If funded, these projects will substantially contribute to the ability of AwwaRF subscribers and other North American water utilities to respond to the many challenges of asset management. It is anticipated that these projects will be considered and built into upcoming research cycles. These projects may also serve as a further basis for continued collaboration among AwwaRF and its many partner organizations engaged in this field.

AWWARF UPDATE ON 2008 FUNDING

Many project ideas were considered by AwwaRF's Research Advisory Council for 2008 Solicited Research Program funding. The AM Research Roadmap projects were considered by 2 goal area workgroups (the Efficient and Customer Responsive Organization and the Infrastructure Reliability workgroups) and the Research Advisory Council. Eleven projects will be funded by the 2008 Solicited Research Program and the Partnership Program, even though twenty-two were identified as high priority. AM ideas were pretty successful in receiving funding; five ideas from the *Asset Management Research Needs Roadmap* are included in the eleven 2008 projects, see Table 3.8:

Table 3.8 AwwaRF's 2008 Projects that originated from *Asset Management Research Needs Roadmap*

AM Research Needs Roadmap	2008 Solicited Research Program or Partnership Program	
Project # and Title	Project # and Title	Objective
1.1) Policies and Strategies to Implement AM Programs 1.2) Organizational Characteristics of Effective AM Programs	4173: Organizational Models, Cultures, Policies and Strategies for Effective Water Utility AM Program Implementation	The project goal is to provide a reference document on organizational models, culture, strategies and policies that will help water utilities create and strengthen the organizational infrastructure needed to implement a formal AM program. Objectives include: • Develop a conceptual framework for water utilities to implement a formal AM program • Identify strategies and policies that will facilitate the implementation of a formal AM program • Identify tools for water utilities to evaluate and understand how elements of culture and organizational structure support implementation of an AM program.
3.2) Develop Guidance Manual for Condition Assessment of Water Main Appurtenances	4188: Condition Assessment of Water Main Appurtenances	Objective Develop a practical guidance manual on the condition assessment of water main appurtenances addressing appurtenance criticality, performance criteria and monitoring, and condition assessment techniques and results.
4.1) Develop and Validate Degradation Curves for Buried Water Distribution System Assets	####: UKWIR Failure Data and Analysis Methodology for Water Mains	The objective is to provide access and participation in the ongoing UKWIR effort to tabulate water supply pipe performance, failure modes and mechanisms. The database has enabled UK water companies to better understand performance of their mains networks and has provided information to produce strategies for longer term asset management.
5.2) Evaluate Strategies for Data Creation, Collection, Validation, and Maintenance for AM including an Asset Data Dictionary	4187: Key Asset Data for Water Utilities	Create a list of terms that explain key drinking water and waste water system assets and performance indicators. The list should focus on appropriate critical asset data – both in breadth (scope) and depth (details) – necessary for strategic asset management. Identify and define assets and explain the systems for classifying them.

The remaining projects and ideas in the *Asset Management Research Needs Roadmap* will be reconsidered in 2009 for funding. The project ideas may be altered after results are made from similar ongoing projects, specifically the projects listed in Table 3.9. For more information on the ongoing projects see Table 3.7 or check the AwwaRF website.

Table 3.9 Comparison of Similar Topics in Current AwwaRF Projects and *Asset Management Research Needs Roadmap* Projects

AM Research Needs Roadmap	Ongoing Research
Project # and Title	Project # and Title
1.3) Prepare Guidance Manual on Level of Service and Metrics	4085: Setting Water Utility Investment Priorities: Assessing Customer Preferences and Willingness to Pay
2.1) Risk Management Protocols Supporting Capital Investments	4126: Tool for Risk Management of Water Utility Assets
3.1) Workshop and Synthesis Document on Condition Assessment of Pre-stressed Concrete Cylinder Pipe	4034: Failure of Pre-Stressed Concrete Cylindrical Pipe
5.1) IT Integration and Data Model to Support AM	4097: Optimizing Information Technology Solutions for Water Utilities

APPENDIX A

WHITE PAPER

White Paper

Review of Asset Management Practices and Needs in the North American Water and Wastewater Industries

Prepared for the
Awwa Research Foundation
Asset Management Research Needs Roadmap
Project No. 4002

Prepared by:

HDR Engineering, Inc.

In Association with

Westin Engineering, Inc.
American Water
John W. Fortin

November 2006

REVIEW OF ASSET MANAGEMENT PRACTICES AND NEEDS IN THE NORTH AMERICAN WATER AND WASTEWATER INDUSTRIES

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FOREWORD

AwwaRF has funded Project 4002 for the purpose of developing an asset management Research Needs Roadmap for water and wastewater utilities that will guide AwwaRF research for the next 5 to 10 year period. The results of the Project will be considered in the 2008 and future AwwaRF research planning.

There are several activities and products that have been developed as part of this project as follows:

3. A White Paper to review the status of asset management and identify research gaps.
4. A Workshop where participating utilities provided input on future research and the Roadmap.
5. Case Studies to illustrate the real world activities that are ongoing.
6. Tailored Asset Management reviews for specific utilities.
7. A final project Report.

This White Paper report was a joint effort developed by HDR Engineering, Inc; Westin Engineering, Inc.; American Water; and John Fortin, Asset Management Consultant and was reviewed by the Project Advisory Committee and AwwaRF staff. There are many opinions regarding asset management, and review and comment by the PAC or AwwaRF does not imply an approval of the content of the document by those parties. The White Paper report was subsequently used by workshop participants as a reference document as they provided input and helped to develop the Research Roadmap.

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EXECUTIVE SUMMARY

This White Paper was prepared as the first step in a project to develop an Asset Management Research Needs Roadmap for the Awwa Research Foundation (AwwaRF). The White Paper reviews current asset management practices in the North American water and wastewater industries. It was designed to provide background information and a common framework for discussion at a workshop held as part of the project in December 2006.

AwwaRF has identified asset management as a field that offers significant value to water and wastewater utilities, particularly for addressing the problem of aging infrastructure. Asset management practices have become increasingly common in nations such as Australia, New Zealand, the United Kingdom and various European nations. However a comprehensive approach to asset management is still relatively new to most North American utilities.

The purpose of the Research Needs Roadmap project is to help AwwaRF define priorities for funding research in the field of asset management. Results of the project will be presented to AwwaRF for consideration in advance of the 2008 research funding cycle.

Definitions of asset management vary widely, but the term generally refers to a structured and comprehensive approach to making informed decisions throughout an asset's life-cycle, regarding construction, maintenance, and renewal. A recent manual (AMSA et al. 2002) defines asset management as:

> …managing infrastructure assets to minimize the total cost of owning and operating them, while continuously delivering the service levels customers desire, at acceptable levels of risk.

While there are many different approaches to asset management, there are common objectives that make the similarities more prominent than the differences. Therefore the Project Team's efforts in preparing this White Paper focus on identifying common elements that water and wastewater utilities will find useful in implementing asset management. For purposes of this White Paper, an idealized set of practices is described and termed *the asset management paradigm*.

Elements of the paradigm are listed in the two boxes on the following pages. In subsequent sections of this paper, each of these elements is compared with actual practices documented in the literature on asset management in North America. This allows gaps to be identified. While there are some exceptions, for the most part comprehensive application of the paradigm is rare in North America at this time.

Several major workshops have been held since 2002 to address needs for development of asset management in the water industry, wastewater industry or both. These events, sponsored by the U.S. Environmental Protection Agency (USEPA), Global Water Research Coalition (GWRC), Water Environment Research Foundation (WERF) and the United Kingdom's Research Foresight Partnership, each resulted in a set of recommended actions. In response to these workshops, the sponsoring organizations and others have launched or are planning to initiate a range of projects. AwwaRF is a participant or joint funder of some of these projects. Additional organizations besides these have also been active in sponsoring research on asset management, both in North America and abroad.

Framework of Asset Management Practices

1. Programmatic Practices

a. Program Management and Organizational Structure

- Vision established with long-term view matched to asset lifetimes
- Organizational culture fosters communication and decision-making across functional boundaries
- Asset performance measures tracked and communicated throughout the organization
- Human resources and training aligned with program objectives

b. Program Development and Evaluation

- Asset inventory designed to provide critical data while avoiding burdensome data management requirements
- Customer service and stakeholder parameters defined and used to manage tradeoffs between cost and performance/reliability
- Risk management framework applied consistently to asset management choices

c. Data Systems and Information Technologies

- Consistent and comprehensive asset identification/nomenclature
- Clear asset hierarchies organized by processes and systems within the utility
- Asset cost assignment to allow clear tracking of maintenance costs
- Assets prioritized for data collection based on criticality to major systems

d. Financial Practices

- Financial policies clearly articulated
- Financial/rate models provide implementation tool for funding asset management program
- Depreciation designed to fund renewal needs over long term
- Financial reporting highlights needs and communicates priorities to Boards and customers
- Financial performance measures linked to overall objectives of asset management program

Framework of Asset Management Practices

2. Asset Life-cycle Practices

a. Asset Creation

- Design considers operational, maintenance and eventual rehabilitation needs
- Full life-cycle costs, including maintenance and renewal considered in capital planning
- Cost-benefit analysis applied consistently to asset management decisions, incorporating financial, social and environmental costs and benefits
- Asset documentation protocols at creation support subsequent maintenance program

b. Operations and Maintenance

- Overall maintenance strategy prioritizes maintenance expenditures based on risk and criticality, with balancing of preventive and reactive maintenance practices
- System for scheduling work and issuing work orders linked to overall strategy and data systems
- Metrics of maintenance work efficiency used to manage life-cycle costs
- Materials management optimized to manage life-cycle costs

c. Physical Condition and Performance Monitoring

- Buried assets accurately mapped with key data recorded for most critical assets.
- Failure data recorded to enable prediction of future trends. Leakage and other performance attributes carefully monitored and data used to inform renewal decisions.
- Above-ground assets monitored for performance metrics and data used to meet defined asset management objectives.

d. Asset Renewal (Rehabilitation and Replacement)

- Risk and criticality explicitly defined and used in renewal decisions
- Cost comparisons used to compare replacement and rehabilitation alternatives in life-cycle framework
- Advances in rehabilitation technology used to minimize life-cycle costs
- Asset creation practices applied as described above

e. Asset Disposal

- Cost-benefit framework applied in selecting disposal alternative
- Environmental and social consequences considered in disposal decisions

The information gathered for this White Paper was used to develop a summary of needs and opportunities with regard to asset management in the North American water and wastewater industries. These needs and opportunities are summarized in Table 6.1 of this White Paper, which begins on page 88. They are grouped into these three categories:

1. Education and training
2. Management tools
3. Physical science and technology

Besides AwwaRF, numerous organizations in the water and wastewater field and other industries are actively sponsoring initiatives involving asset management. Collectively these initiatives address, at least in part, each of these three categories of needs. Since these various efforts are unfolding at this time, it is difficult to evaluate how effectively they will meet the needs identified in Section 6. This is particularly true of initiatives in Category 1 (education/training) and Category 2 (efforts to improve and disseminate practical tools). Their actual contribution to asset management development will not be known for some time to come.

In this environment, the challenge for AwwaRF is how to deploy resources to complement these ongoing efforts and meet needs that would otherwise not be met. This requires consideration not only of needs in the water industry, but also of AwwaRF's particular orientation and capabilities.

From a needs perspective, it appears the greatest opportunity for advancing asset management in North America is to provide education and training throughout the industry (Category 1). Education is needed to demonstrate the value of asset management to upper level utility managers and their governing boards since these are the internal leaders with the ability to launch and lead asset management initiatives. In this area, education on financial planning may offer the greatest leverage, as this area can prompt action in all the other areas of asset management. Education and training are also needed to provide staff at all levels of utility organizations with the skills and knowledge needed to make asset management practical and demonstrate concrete benefits.

While the need in Category 1 is great, this is not the best area for AwwaRF activity. This is because other types of organizations such as AWWA, EPA, universities and technical institutes are more suitable for leading education and training initiatives. Therefore AwwaRF's strategy in this regard should be to maintain links with organizations developing education and training programs. These links can be instrumental in ensuring training materials expressly consider water industry issues. In addition, contact with organizations sponsoring education and training programs offers a channel through which non-proprietary information developed by AwwaRF can be disseminated to many users. This can complement AwwaRF's traditional channels for distributing research results.

AwwaRF is better suited to make direct contributions in Category 2. Improvement of available management tools and techniques or development of new ones will enable utilities that have embarked on the asset management journey to make their programs successful while avoiding inefficiencies in areas of common need. Areas of greatest need appear to be practical methodologies for risk assessment/risk management, life-cycle cost analysis, and cost-benefit analysis. Development of a standard framework for information and data management in water utilities could also offer significant benefits. For each of these topics, there is a need to improve tools targeting the specific issues or the water industry. Information from other industries is available and adaptation of these approaches for the water industry is one area where gains could be made rapidly.

Similarly, AwwaRF is well-equipped to sponsor research in Category 3. Advances in science and technology are needed so that financial resources available for buried pipe renewal are spent as effectively as possible. The greatest needs in this area appear to be improved abilities to assess the condition and performance of buried pipes and to predict their rate of performance deterioration. Technologies for extending the lifetime of assets also have high value.

The benefits of Categories 1, 2 and 3 can also be differentiated in terms of timing. At this time, the North American water and wastewater industries may be more in need of new activity in Categories 1 and 2, rather than Category 3. This is because, as long as the basic practices of asset management are not yet being used, advanced science and technology cannot be used to the greatest advantage. However, science and technology take time to develop. It is important to recognize needs that must be met five to ten years in the future and provide sufficient lead time to develop solutions. Therefore, while Categories 1 and 2 appear to be the greatest immediate priority, there is also a high value now in funding Category 3 activities.

At the present time there are many opportunities for AwwaRF to collaborate with other organizations on asset management initiatives, both within North America and overseas. It is suggested AwwaRF remain actively engaged with partner organizations for purposes of coordination and to promote dissemination of effective practices and newly emerging knowledge. At the same time AwwaRF should carry out additional work on topics that are both critical and unique to potable water utilities.

This White Paper has assembled and organized information as a first step in developing AwwaRF's Asset Management Research Needs Roadmap. The categories and topics presented above were discussed further at the workshop. Workshop participants were asked to apply their knowledge and experience to recommend projects and priorities for AwwaRF activity to further advance the practice of asset management in North America. The results of this process were then incorporated into a Research Needs Roadmap document, separate from this White Paper.

1.0 BACKGROUND AND PURPOSE

Water and wastewater utilities in North America face substantial infrastructure challenges in managing infrastructure they own and operate. These challenges are expected to grow steadily for at least the next two decades. In recent years the field of asset management has emerged as a means of addressing these challenges. While there is growing awareness and application of this field internationally, it is still relatively unfamiliar to most utilities in North America.

The Awwa Research Foundation (AwwaRF) has collaborated with other organizations to develop practical tools for managing physical assets of water utilities. Partners have included the Water Environment Research Foundation (WERF); United Kingdom Water Industry Research Limited (UKWIR); Commonwealth Science and Industrial Research Organization (CSIRO), National Research Council (NRC) of Canada, the Netherlands organization Kiwa Water Research and others.

In order to provide clear direction for its research efforts, AwwaRF commissioned this review of current asset management practices and outstanding needs in the water and wastewater industries. This review will be used to establish priorities for AwwaRF's research program in this field for 2008 and beyond. Research priorities will be detailed in a "Research Needs Roadmap" on asset management.

The field of asset management has been growing internationally and techniques developed abroad are gradually being applied and adapted to the North American context. This paper focuses on how the field can be further advanced in North America.

This White Paper documents findings from a literature review and uses these findings to prepare a list of candidate topics needing further research and development attention in coming years. This information was used at a workshop of water and wastewater professionals to jointly advise AwwaRF on research projects and priorities. Results from the workshop will be refined by the Project Team and presented to AwwaRF for consideration in advance of the 2008 funding cycle.

1.1 WHAT IS ASSET MANAGEMENT?

Definitions of asset management vary widely, but the term generally refers to a structured and comprehensive approach to making informed decisions throughout an asset's life-cycle, regarding construction, maintenance, and renewal. A recent manual (AMSA et al. 2002) defines asset management as:

> …managing infrastructure assets to minimize the total cost of owning and operating them, while continuously delivering the service levels customers desire, at acceptable levels of risk.

Asset management has been applied in fields as diverse as transportation, electric power and manufacturing (USDOT 1999; EPRI 2006; Fortin et al. N.d.). Like the water and wastewater industries, all of these require significant investments in long-lived capital facilities that must meet critical service and reliability objectives. In each of these industries, a body of research has emerged on asset management.

Asset management can vary substantially as practiced by different organizations. This divergence can be attributed to differences among organizations in terms of their industries and applicable technology, size and organizational resources, cultural differences from one nation to another, and different regulatory and business contexts across nations and industries.

Even within a narrower context such as the North American water and wastewater industries, asset management needs and practices can vary from one utility to another. Utilities that are just beginning to initiate asset management practices will have different needs than organizations that have well-developed programs with a longer track record of performance. Moreover, utilities with rapidly growing service areas and a relatively young distribution or conveyance network will emphasize different asset management techniques than utilities with a stable customer base and facilities nearing the end of their useful lifetimes. Perhaps because of these factors, the U.S. General Accounting Office (USGAO) noted that formal asset management approaches vary considerably in U.S. water and wastewater utilities (USGAO 2004).

Despite these diverse contexts for applying asset management, the literature on asset management consistently identifies several key objectives. These include:

- Asset management seeks to *manage costs* of constructing and operating capital facilities over their full life-cycles (Hughes 2006a, USGAO 2004, AMSA et al. 2002).
- Asset management seeks a systematic, rational and comprehensive basis to *establish priorities* among alternative expenditures (both capital and non-capital) (USDOT 1999, AMSA et al. 2002).
- Asset management *addresses tradeoffs* between risk and reliability (Hughes 2006a).
- Asset management improves *prediction of financial needs* in upcoming years allowing improved management of rate-setting and improved relationships between utility managers, governing bodies and the public (AMSA et al. 2002).
- Asset management supports *integration of desired outcomes* in terms of business goals, customer service criteria, engineering considerations and operational factors (USDOT 1999, AMSA et al. 2002).

With these objectives in mind, the similarities in asset management practices become more prominent than the differences. Therefore, the Project Team’s efforts in preparing this White Paper center on identifying common elements that water and wastewater utilities will find useful in implementing their asset management programs.

1.2 INFORMATION PRESENTED IN THIS WHITE PAPER

This White Paper surveys the many dimensions of asset management as applicable to the water and wastewater industries in North America. Asset management is in reality a suite of interrelated elements spanning planning, engineering, maintenance, financial management, and other utility functions. An idealized set of practices is identified for each of these elements. Collectively, this White Paper calls this idealized set of practices the *asset management paradigm*.

Practices within the asset management paradigm can be organized into categories as shown in the two boxes on the following pages. In each of the following sections of this White Paper the asset management paradigm is described for each category individually. Actual practices by North American water and wastewater utilities are compared with the asset management paradigm to uncover needs and gaps that could be remedied by new research or other assistance. The information presented is based on a literature review conducted as part of this project, supplemented by the professional knowledge of the authors.

This paper also shows which of these needs may be met by research activity already being funded or planned by AwwaRF and other organizations. Remaining needs are considered as candidates for further investment in research and development.

Framework of Asset Management Practices

1. Programmatic Practices

a. Program Management and Organizational Structure

- Vision established with long-term view matched to asset lifetimes
- Organizational culture fosters communication and decision-making across functional boundaries
- Asset performance measures tracked and communicated throughout the organization
- Human resources and training aligned with program objectives

b. Program Development and Evaluation

- Asset inventory designed to provide critical data while avoiding burdensome data management requirements
- Customer service and stakeholder parameters defined and used to manage tradeoffs between cost and performance/reliability
- Risk management framework applied consistently to asset management choices

c. Data Systems and Information Technologies

- Consistent and comprehensive asset identification/nomenclature
- Clear asset hierarchies organized by processes and systems within the utility
- Asset cost assignment to allow clear tracking of maintenance costs
- Assets prioritized for data collection based on criticality to major systems

d. Financial Practices

- Financial policies clearly articulated
- Financial/rate models provide implementation tool for funding asset management program
- Depreciation designed to fund renewal needs over long term
- Financial reporting highlights needs and communicates priorities to Boards and customers
- Financial performance measures linked to overall objectives of asset management program

Framework of Asset Management Practices

2. Asset Life-cycle Practices

a. Asset Creation

- Design considers operational, maintenance and eventual rehabilitation needs
- Full life-cycle costs, including maintenance and renewal considered in capital planning
- Cost-benefit analysis applied consistently to asset management decisions, incorporating financial, social and environmental costs and benefits
- Asset documentation protocols at creation support subsequent maintenance program

b. Operations and Maintenance

- Overall maintenance strategy prioritizes maintenance expenditures based on risk and criticality, with balancing of preventive and reactive maintenance practices
- System for scheduling work and issuing work orders linked to overall strategy and data systems
- Metrics of maintenance work efficiency used to manage life-cycle costs
- Materials management optimized to manage life-cycle costs

c. Physical Condition and Performance Monitoring

- Buried assets accurately mapped with key data recorded for most critical assets.
- Failure data recorded to enable prediction of future trends. Leakage and other performance attributes carefully monitored and data used to inform renewal decisions.
- Above-ground assets monitored for performance metrics and data used to meet defined asset management objectives.

d. Asset Renewal (Rehabilitation and Replacement)

- Risk and criticality explicitly defined and used in renewal decisions
- Cost comparisons used to compare replacement and rehabilitation alternatives in life-cycle framework
- Advances in rehabilitation technology used to minimize life-cycle costs
- Asset creation practices applied as described above

e. Asset Disposal

- Cost-benefit framework applied in selecting disposal alternative
- Environmental and social consequences considered in disposal decisions

2.0 PROGRAMMATIC PRACTICES

This section addresses the overall programmatic practices that are part of the asset management paradigm (see box in Section 1.2). These are practices that relate to the utility organization or asset management program as a whole, and therefore apply throughout the various life-cycle stages of an asset.

2.1 PROGRAM MANAGEMENT AND ORGANIZATIONAL STRUCTURE

An asset management program can succeed only if supported by an informed management and appropriate organizational structures. This section examines how utility organizations are structured to carry out effective asset management practices, human resource needs and training, and the definition and use of metrics to measure and monitor performance of equipment and systems.

2.1.1 Vision and Time Frame

Asset management programs need to be infused with a clear vision, including definition of appropriate time frames. Asset management inherently takes the long view in its effort to manage life-cycle costs. However, a recent review of the water industry concluded that one problem is the short-term focus typical of the elected bodies that oversee public water and wastewater utilities (USGAO 2004). The same problem can affect private utilities. In this circumstance it is difficult to avoid having the short-term focus carry over into the outlook of upper management, and transmitted throughout the utility. This short-term view hampers effective life-cycle management.

A suitable vision can be formally established and supported by embedding the asset management program in the utility's business plan, as adopted by its governing body. As such, the program should be treated similar to a capital project, with a defined budget, assigned staff, and schedule with milestones.

2.1.2 Organizational Culture

One of the key objectives of asset management is to minimize life-cycle costs of delivering utility services at a given service level. Because of this core objective, the asset management paradigm emphasizes integration of decision-making on expenditures and investments across functional categories. This allows tradeoffs between different functional categories to be recognized and evaluated so appropriate choices can be made that are linked to overall utility management and service objectives (USDOT 1999).

One way to foster integrated decision-making is to structure utility organizations in an integrated fashion that promotes communication across functional "silos" within the organization. Hence, the literature on asset management emphasizes the importance of organizational integration, sharing of data that transcends asset classes, and fostering of communication channels both vertically and horizontally within the organization (USDOT 1999, Allbee 2005). One large utility found that forming cross-functional teams was effective for implementing change and facilitating "buy-in" from staff (Colbert et al. 2002). The teams were comprised of staff senior management, union leaders, procurement, engineering, maintenance trades, and operators, with support from consultants.

In many utilities, organizational integration will require "cultural change" that fosters collaborative perspectives among utility employees and managers (USGAO 2004). Business processes may need to be redesigned (AMSA et al. 2002). Both the culture and the organization must be aligned in a collaborative framework in order to sustain the asset management program. In addition, executive sponsorship is critical to carrying out culture change (Fortin et al. N.d.).

Some utilities in the water and wastewater industries have undertaken organizational integration in keeping with the asset management paradigm as described above. For example, the Massachusetts Water Resources Authority (MWRA) approached this at the local plant level using implementation task teams and new positions dedicated to asset management. Seattle Public Utilities (SPU) has adopted an organization-wide approach. Regardless of the scale of the effort, leaders of various program elements need to have a clear charter, sufficient resources and diverse participation within the organization (Fortin et al. N.d.).

By and large, however, utility organizations tend to experience barriers at functional boundaries, such those among engineering, planning, operations, and finance departments. Even within these functional categories there can be significant compartmentalization, such as divisions between the treatment plant and distribution system within a water utility. Lines of communication and decision-making typically run vertically within these functional "silos," hampering integrated decision-making on maintenance expenditures and capital improvements. (USGAO 2004, WERF 2002, Allbee 2005). This lack of integration is true at both the operational level and the management level in many organizations (USGAO 2004). Indeed, some involved in the water and wastewater industries suggest the biggest hurdles of asset management in North America are not technical, but organizational (WERF 2002).

2.1.3 Performance Measures

It is often said that "what gets measured, gets managed." Effective use of performance measures is a key component in ensuring an asset management program serves broad management and service objectives. This is particularly true in the arena of operations and maintenance, but can also apply to enterprise-wide activities. Recognition of the importance of performance measures is strong in other asset-intensive industries such as transportation, electrical power, steel production and petrochemicals (USDOT 1999, Pennsylvania State University N.d.).

Benchmarks, metrics and key performance indicators can identify opportunities for improvement, measure progress, and manage improvement processes. They also can be used to monitor performance of specific processes, systems, equipment and components (Pennsylvania State University N.d.).

In order to be effective, asset management metrics must not only be tracked, but communicated throughout the organization, with the aim of prompting appropriate responses (NASA 2000). Improvements in technology now enable this to be done inexpensively, in real time (Brueck 2000). In addition, metrics are most likely to be implemented effectively if personnel at multiple levels of the organization are involved in designing metrics that produce valuable information for day-to-day work processes.

In comparison with this paradigm, several authors have concluded that the water and wastewater industries need improvement in terms of developing prioritized performance measures, targeting performance measures to the "right" performance objectives, and improved tools and training in this arena (Matichich et al. 2006, Brueck 2000, Brueck 2005).

2.1.4 Human Resources and Training

Review of the suite of practices contained within the asset management paradigm makes it clear that a variety of specialized skills are needed in the human resources portfolio of organizations implementing asset management. These skills extend beyond the traditional management, engineering and operations skills employed at water and wastewater utilities. They include skills in economic analysis, risk assessment, data management, and the use of specialized equipment for condition assessment and predictive maintenance programs.

Training and recruiting practices need to be carefully structured and resources provided to enable utility staff to develop the skills needed to apply new techniques. Once asset management program elements have been selected and implemented, job descriptions should be updated to include the required skills and staff training provided. Where necessary and economical, in-house skills can be supplemented by skills obtained through outsourcing.

At least one author has observed that water and wastewater utilities typically do not have the skills needed for risk assessment and some other asset management activities (Allbee 2005). Skills in supporting technologies like GIS may also restrict effective implementation. A utility's success in implementing asset management will therefore be constrained by the human resource limitations.

Training is essential to adopting and sustaining the use of new tools and techniques. For an asset management program to become successful, it is important to ensure staff understands the new programs and their associated benefits. In addition to training on specific applications such as the Computerized Maintenance Management Systems (CMMS) and condition monitoring, training should also be developed for new maintenance work management procedures (Fortin et al. N.d.).

Some institutions have complete internal training departments while smaller organizations rely on the management team. Whether large or small, managers need to understand that there is a return on investment and opportunity for increased staff morale in keeping staff skills current.

The literature review did not identify specific information on the adequacy of training programs to support asset management. However, there is clearly a need in this area.

2.2 PROGRAM DEVELOPMENT AND EVALUATION

Water and wastewater utilities have always owned physical assets and have made decisions in each stage of the asset life-cycle. From that perspective, utilities have been engaged in asset management for many decades, with or without calling it that. What is new today is that attention to the problem of aging infrastructure has heightened the importance of making decisions using sound economic principles. In addition, the development and documentation of asset management practices overseas and in other industries has offered new models of decision-making for consideration.

If new practices are to be applied or adapted in the North American context, they will be grafted onto a body of existing assumptions and practices. Current protocols for making short- and long-term asset decisions are typically ingrained in utility organizations. Whether a utility undertakes limited modification of selected practices or a wholesale restructuring of asset management activities, changes to existing practices require careful forethought and commitment.

Issues of program development are found throughout this White Paper, since they go hand-in-hand with specific asset management practices. This section highlights three distinct, cross-cutting issues in program development, namely:

- Acquiring or improving asset inventory data[1]
- Recognizing the role of customer service parameters in defining the asset management program
- Incorporating the utility's framework for risk management

Since program development is an iterative process, these issues will also emerge as part of ongoing program evaluation.

2.2.1 Asset Inventory

One key element in developing an asset management program is developing an inventory of infrastructure and plant assets. This requires a number of decisions to be made in terms of organizing asset hierarchies by factors such as location and/or system; tagging the assets themselves; developing asset nomenclature that is consistent across utility departments; and defining attributes for different types of assets that should be recorded. These choices have a significant impact on the usefulness of the asset inventory (Matichich et al. 2006).

Asset management is supported by asset information such as:

- Age, condition, location
- Size and capacity
- Manufacturer and construction materials
- Installation data and expected service life
- Maintenance and performance history (USGAO 2004)
- Criticality, derived from the utility's risk management framework

Other attributes may be suitable for various asset classes. For example, specific data needed on pumps in a water treatment plant will differ from information on distribution lines. Where prediction of failure trends is desired, additional data related to specific failure modes may be beneficial.

While asset data are clearly needed, some argue that it is a mistake to emphasize collection of data over tools for putting the data to use in prioritizing maintenance and renewal activities (Cromwell et al. 2001, WERF 2002, Matichich et al. 2006). Collection and maintenance of data on assets needs to be carefully designed to serve key objectives without incurring excessive costs (USDOT 1999). One approach is to limit gathering of new data only to the most critical assets, as defined through risk assessment. Another approach is to build data collection into routine repair and maintenance activity, so asset inventory can be improved incrementally (USGAO 2004).

The United States General Accounting Office found that many utilities lack effective asset inventory information (USGAO 2004). WERF has identified improvement of asset inventories and attribute information as a key research need (WERF 2002).

[1] Further information on data systems is covered in a separate section of this White Paper.

Additional information on data systems and data management is presented in a separate section of this White Paper.

2.2.2 Customer Service and Stakeholder Parameters

Many published works on asset management place customer service parameters at the heart of the asset management program (AMSA et al. 2002, Allbee 2005, Grigg and Blaha 2005). This is particularly true of asset management examples from Australia and New Zealand (WERF 2002). Customer considerations include their expectations with respect to service reliability; and willingness to pay for alternative levels of service (Grigg and Blaha 2005). Asset managers from New Zealand and Australia suggest that customers are able to understand the tradeoffs between reliability and cost, and do not always desire the highest level of reliability without regard for cost (WERF 2002).

Besides customers, other stakeholders also have a role in defining program parameters (Grigg and Blaha 2005). The public at large is affected by construction activities that disrupt traffic, or create noise and other impacts (Grigg and Blaha 2005). In the United States asset decisions must be informed, in part, by regulatory requirements under the Safe Drinking Water Act for water utilities and the Clean Water Act for wastewater utilities. Therefore regulatory agencies such as the U.S. Environmental Protection Agency (USEPA) and its state government counterparts form another group of stakeholders. Some utilities report that bond rating agencies have a keen interest in asset management practices (Matichich et al. 2006). For publicly-owned utilities, elected boards and their constituents clearly take an interest in core utility functions such as asset management. For private utilities, boards and stockholders have an opportunity for input on asset management decisions.

Therefore, in developing or upgrading an asset management program, utility managers need to determine how customer needs and wants, regulatory requirements, and stakeholder issues will be factored into program design. In the United States, alternate levels of customer service are not well studied. Many utilities embed their practices in an assumption that customers simply want 100% reliability at all times (Templin 2005). Regulatory requirements have received extensive attention by utilities and are well documented in water and wastewater industry literature. However, there has typically been little interplay between asset management programs and regulatory programs to highlight areas for negotiation or improvement.

AwwaRF has funded work on the topic of customer perceptions, attitudes and expectations. Damodaran et al. (2005) developed survey data on customer willingness to accept supply disruptions, as well as means of communicating planned disruptions to utility customers.

2.2.3 Risk Management Framework

Every decision-maker applies some theory of risk, whether consciously or unconsciously. Advanced techniques for asset management seek to formalize risk assessment, allowing tradeoffs to be explicitly evaluated and addressed. For example, asset management requires choices between continued maintenance of an aging asset, versus investment in rehabilitation or replacement. Prioritization among different assets is also a key to effective asset management. In the area of buried assets, choices also involve the amount of investment to be made in assessing asset condition. Because all of these choices involve uncertainty, risk management permeates the practice of asset management (Hughes 2006a, UKWIR 2005, Harlow and Buckland 2005).

Most North American water and wastewater utilities lack skills in formal risk assessment (Allbee 2005, Harlow and Buckland 2005). This makes it impossible to establish a consistent approach to managing risk across the organization.

Without well-established frameworks for addressing risk, utilities also lack direction in gathering data that could assist in risk management (Harlow and Buckland 2005). This deficiency is most apparent with below-ground assets. Lacking effective and economical methods to assess the condition of buried assets (and in some cases, to even locate assets), utilities are hampered in their risk management decisions. Utilities need far more understanding in terms of the risk factors involved and the probability and consequences of asset failure.

Some organizations use a Root Cause Failure Analysis (RCFA) as a formal means to investigate incidents that have safety, environmental or large financial impacts. The goal is to minimize the risk of recurrence of such events through a structured review process. This can be another element of a comprehensive asset management program.

However, RCFA is often not used. As a result, failures are repaired or facilities replaced, without identifying the root cause of the problem. There is a need for utility managers to understand this tool is available and offers significant value in minimizing the risk of repeat failures and their associated costs.

2.3 DATA SYSTEMS AND INFORMATION TECHNOLOGIES

Under the asset management paradigm, accurate and up-to-date data is used to evaluate and monitor asset condition and performance, develop performance measures and objectives, and assess asset values. Operating systems such as the CMMS must be populated with accurate data to ensure work orders are correct and maintenance labor is used efficiently. Data are also used to continually monitor effectiveness of the asset management program itself.

Essential elements in an asset management data system include the following (Templin 2006).

- Asset Identification. Each asset must be assigned a unique identifying code. Uniform identification allows information about asset performance to remain consistent across an entire system.
- Asset Hierarchies. This stair-step hierarchy allows roll-up of costs, performance, and systems reliability from the least asset in a system to the major processes, systems, and utilities to which a group of assets belong.
- Asset Cost Assignment. Charges for direct or burdened labor, depending on accounting procedures of the enterprise, are applied to assets through the work order system in the CMMS.
- Asset Prioritization. Rather than perform routine proactive maintenance on everything, responses to performance anomalies are guided by asset priorities. Such methods result in considerable resource savings, and allow time and attention to be directed toward the most important assets and processes.

Data can be effective only if utilities first develop a clear strategy for uses of data (Templin 2005). Since data acquisition is expensive, an effective asset management program will then use the risk-management process and related assessment of criticality to guide data collection aimed at these uses. The utility should develop data standards (e.g., asset nomenclature), data quality assurance/quality control and a clear and well-communicated structure for data flow within the organization.

In addition to these elements, the asset management paradigm involves providing connections between data systems, such that information can be accessed and used in an integrated fashion to support decision-making.

In a review of asset management practices in the water industry nationwide the U.S. GAO found that collecting and managing data are key challenges for implementing asset management. Data currently held by utilities are often incomplete, outdated or inaccurate. This problem is compounded by the fact that data needed for comprehensive asset management are typically stored in multiple databases that are incompatible with one another, hampering coordination of data across departmental boundaries within a utility. This is not surprising, since data systems often are specified and procured within functional categories. Further, data formats vary, and even nomenclature for individual assets owned by a utility may be different from one department or work crew to another (USGAO 2004).

A variety of data management systems are currently used by North American utilities. These include Supervisory Control and Data Acquisition (SCADA), Computerized Maintenance Management Systems (CMMS); Enterprise Asset Management Systems (EAM), Laboratory Information Management System (LIMS), Geographic Information Systems (GIS) and various financial management data systems. Systems may be hybridized or customized to meet unique needs, especially for larger utilities. The variety of data systems poses challenges for data integration and can be confining for a utility with a large "sunk cost" in its existing data systems.

This problem is not unique to the water industry. The U.S. Department of Transportation has identified similar problems hampering asset management for state highway departments. The agency has prepared a basic manual on data integration to help overcome these challenges. USDOT also observed that transportation agencies typically lack experienced staff with data management knowledge and skills. One trend countering these challenges is improvements in information management technology that now permit even smaller organizations to tackle data integration (USDOT 2001).

Facilitation of utility-to-utility user groups centered on certain widely used software platforms could help utilities improve data management and data integration. This approach has been found to work in other specialized fields.

In addition, it may be useful to develop standard criteria for assembling, reviewing and formatting basic asset data. Guidance on updating data during routine maintenance functions could also assist utilities in this area.

2.4 FINANCIAL PRACTICES

Asset management requires prudent and adequate funding to assure long-term infrastructure sustainability. A key component in determining prudent and adequate funding levels is the financial planning process. The financial planning process centers around the establishment of financial policies/practices and the development of a long-range financial plan.

The asset management paradigm includes financial planning to aid utilities in planning for future maintenance and repair costs and "smoothing" rate adjustments over time (AMSA et al. 2002, Nagel and Elenbass 2006). To fully realize these benefits, a utility must apply financial practices that are integrated with other elements of the asset management program. For example, establishing adequate funding levels helps the utility to avoid deferring maintenance that should be done to minimize life-cycle costs.

This section addresses five aspects of financial practices for which this integration is key:

- Establishing Written Financial Policies
- Development of Financial Planning/Rate Models
- Treatment of Depreciation (Funding of Rehabilitation and Replacement)
- Financial Reporting/Development of a Financial Plan
- Financial Performance Measures/Guidelines

Considering these items in the context of asset management will assist utilities to maintain their financial health in the future. This is particularly true for smaller utilities, which often face financial demands that are significantly greater than their revenue-generating capacity (Jordan et al.1997).

2.4.1 Establishing Written Financial Policies

Development and adoption of a set of financial policies around which financial plans and rates are consistently established is an important policy tool. Clearly stated financial and rate setting policies provide the foundation and guidelines around which the long-term plan and rates are established. In essence, written financial policies establish the "rules" around which the governing body desires to review rates. In this process of establishing these policies, there are a number of benefits to the governing body and utility management. Among these benefits are the following:

- Provides management with clear policy direction on financial planning and rate setting parameters
- Provides consistent and logical financial/rate (business) decisions
- Provides future governing bodies with the basis or reasoning behind past decisions (documentation)
- Helps the utility's customers better understand the governing body's financial planning/rate setting philosophy
- Provides a strong message to the outside financial and banking community (bond ratings)

The establishment of written financial planning/rate setting policies is not intended to replace existing financial policies, but rather, complement and enhance the existing policies, particularly as they relate to the development and establishment of capital improvement projects and funding. Among the types of financial policies that may be adopted are the following:

- Establishment of a rehabilitation and replacement reserve fund
- Establishment of minimum reserves levels
- Establishment of target debt service coverage ratios for financial planning purposes
- Establishment of a minimum annual rate funding for rehabilitation and replacement capital projects
- Annual review of the financial plan/rates

2.4.2 Development of Financial Planning/Rate Models

The development of a financial planning/rate model begins the process of quantifying the financial and rate impacts of an asset management program. More importantly, a financial planning/rate model provides the basis for funding the asset management program.

Financial planning/rate models are developed to determine a utility's cost of providing and maintaining service, and to determine how funding sources will be combined to pay for those costs. By coordinating with and integrating other elements of asset management (e.g., condition and performance monitoring, data systems and information technologies), a utility's financial model can more accurately depict the system's revenue requirements, particularly for asset rehabilitation and replacement (R&R). This can translate to efficiency in resource allocation and equity of cost allocation to all customers, including cross-generational equity for long-lived assets (Cromwell et al. 2001).

In practice, many utilities have not incorporated an asset management philosophy into their financial/rate models. Specifically, most water and wastewater systems are deficient in how they account for R&R capital infrastructure projects. Some utilities simply include a line-item in their budgets for annual R&R costs, based on a cursory review of overall historical costs. Others do not account for such needs at all in their financial models (Jordon, Carlson, and Wilson 1997). The result is that for the majority of utilities, rates are established at levels inadequate to cover the full cost of service over the long term (Allbee 2005). A 2002 USGAO report indicates that 29% of drinking water utilities and 41% of wastewater utilities do not generate enough revenue to cover their full cost of service (USGAO 2004). WERF has also identified the calculation of revenue needs and incorporation of asset management into financial models and rate forecasts as an area in need of improvement (WERF 2002).

At a minimum, a financial planning/rate model should provide a tool that is capable of providing the following key decision-making information for an extended planning time horizon:

- For each year, calculation of net income such that revenues exceed expenses
- Determination of a detailed capital project funding plan that specifies
- The total amount of capital projects
- The various funding sources including the amount and cost of long-term debt and rate-financed R&R funding
- Determination of the ending reserve fund balances in comparison to targeted/planned reserve levels
- Calculation of debt service coverage ratios (rate covenants)
- Specification of the annual rate adjustments needed to support the financial plan

A financial planning/rate model need not be overly complex, but it must be capable of providing a number of key pieces of information, and have the ability to allow the user to modify key inputs to develop various scenarios.

2.4.3 Treatment of Depreciation (Funding of Rehabilitation and Replacement)

Depreciation is the accounting treatment of allocating the cost of a fixed asset over its assumed beneficial (useful) life. There are a number of issues associated with using depreciation expense for financial planning purposes. Among these issues are the differences between the accounting "useful life" and the actual service life of the asset. In addition, many utilities have donated or contributed assets that were placed on the utility's asset records far below the actual cost of the asset (e.g., $1). Finally, all utilities recognize that there is a distinct difference between the concept of depreciation expense and actual replacement cost. Even with those caveats and issues, depreciation expense is an important concept from a financial planning and rate setting perspective.

In researching the issue of depreciation, the treatment of depreciation is highlighted as an important issue in the context of financial models. Analysts suggest that the use of geometric depreciation curves best reflects the cash flow needed to maintain and replace buried assets (Cromwell et al. 2001, Anonymous 2001). A geometric curve reflects the fact that renewal funding needs increase sharply in the late stages of the asset life-cycle. However the majority of U.S. utilities continue to use straight-line depreciation in their accounting practice and financial models.

There are many barriers to implementing alternative depreciation methods. These include:

- Lack of information regarding the magnitude and timing of future asset failures.
- Constraints on accounting practices under state law.
- Depreciation is not always even used to calculate revenue requirements. Under the "cash basis" methodology, depreciation expense is not a cost component within the revenue requirements. Introduction of this concept may require a substantial modification to some financial frameworks.
- Changing depreciation methods affects cross-generational cost burdens. Future elected leaders may not honor deferred revenue requirements.
- Where assets are already nearing the end of their useful lifetimes and depreciation has historically been straight-line, changing the depreciation method may not address problems (Cromwell et al. 2001).

The reviewed literature does not offer specific guidance on ways in which to construct a modified depreciation approach, but suggests that utilities will find it easier to make such changes as other elements of their asset management programs mature, particularly regarding the recording and management of asset condition assessment data, and failure prediction (Cromwell et al. 2001).

At the very least, annual depreciation expense does provide a utility with a very simple measure to fund those assets being depreciated. As an example, USEPA user charge regulations require the funding of O&M and replacement costs associated with the sewer system. The replacement component can be partially funded by including the amount of annual depreciation expense for the facilities. Prudent financial planning would suggest that a utility should annually fund, at a minimum from rates, an amount equal to or greater than annual depreciation expense. The amount over and above annual depreciation expense is reflective of the issue of replacement cost versus depreciation expense.

2.4.4 Financial Reporting/Development of a Financial Plan

One catalyst that is driving utilities to seek new approaches to financial models (particularly with respect to R&R funding) comes from recent financial reporting requirements for general infrastructure assets set forth in Governmental Accounting Standards Board (GASB) Statement 34, released in 1999 (Matichich, Allen and Allen et al. 2006). GASB 34 offers a "modified" or "optional" method by which state and local governmental entities may report on their components of infrastructure. Under this approach, infrastructure assets that are part of a network or subsystem of a network are not required to be depreciated as long as two requirements are met:

- The entity manages the eligible infrastructure assets using an asset management program.
- The entity documents that the eligible infrastructure assets are being preserved approximately at (or above) a condition level established and disclosed by the entity (AMSA et al. 2002).

Most water utilities are organized as enterprise funds (for the purposes of financial reporting) and are therefore not subject to the requirements of the asset management reporting option. Their requirements are in most cases limited to documenting and depreciating assets (Matichich, Allen and Allen 2006). However, the GASB 34 reporting options can be used to highlight the importance of infrastructure, communicate renewal needs to customers and elected decision-makers, increase the recognition of infrastructure costs, and meet service objectives (AMSA et al. 2002; Matichich, Allen and Allen 2006).

A more recent GASB reporting requirement pertinent to water and wastewater utilities was issued in 2003. GASB Statement 42 establishes accounting and financial reporting standards for impairment of capital assets. A capital asset is considered impaired when "its service utility has declined significantly and unexpectedly" (GASB 2003). This GASB statement is intended to improve financial reporting by requiring governments to report the effects of asset impairment when they occur, as opposed to reporting them as a part of ongoing depreciation expense or upon disposal. The literature reviewed for this White Paper does not address the implications that GASB 42 may have for water and wastewater utilities.

A primary challenge in implementing changes to financial reporting practices is that present governmental accounting is not uniform nationwide. For example, target ratios that treat one-time capital payments (e.g., impact fees) as revenues differ amongst utilities (Jordan et al. 1997). WERF has identified financial reporting (and specifically, to GASB standards) as an area in need of improvement (WERF 2002).

From a practical standpoint, the development of an asset management plan and financial/rate plan will directly address many of the concerns that created the new GASB rules. Simply stated, the nation's deteriorating infrastructure caused sufficient concern to warrant the need for improved financial reporting of assets and infrastructure.

2.4.5 Financial Performance Measures/Guidelines

There are a variety of methods that may be used to establish financial planning guidelines for R&R. As noted previously, depreciation expense is one simple method that is often used to judge R&R funding. Performance measures such as the budgeted amount for maintenance expressed as a percentage of asset value can also be used as one tool in an asset management program (NASA 2000). While most utilities use measures of financial performance, it is not clear that those measures are directly linked to overall objectives of long-term asset management.

3.0 ASSET LIFE-CYCLE PRACTICES

Individual assets owned by water and wastewater utilities have a "life-cycle" as indicated in the box in Section 1.2. This life-cycle includes asset creation, operation and maintenance, renewal, and eventually decommissioning or disposal. Within each stage of the life-cycle, there are specific practices that are part of the asset management paradigm. This section examines those practices and compares them with actual utility experiences in North America.

3.1 ASSET CREATION

Many water and wastewater utilities across North America are actively expanding or improving facilities to meet the needs associated with population growth and regulatory requirements. Asset management provides a framework for making decisions about new infrastructure as it is planned and financed. The key elements of the asset management paradigm in this regard are:

- Analysis of the full life-cycle cost of each asset that is created or acquired. This allows capital costs and O&M costs to be considered in a single decision framework;
- Application of systematic cost-benefit analysis for major project decisions. Depending on the project involved, risk assessment may be an important element of the cost-benefit analysis.
- In one variant of the asset management paradigm, cost-benefit analysis is extended to account for the "triple bottom line," encompassing financial impacts, social impacts, and environmental impacts (SPU N.d.).

These practices also apply to other life-cycle stages such as asset renewal (i.e., rehabilitation and replacement).

3.1.1 Analysis of Life-Cycle Costs

The asset management paradigm calls for explicit analysis of full life-cycle costs. This allows the cost of different alternatives of delivering a specified level of service to be compared, including both up-front costs of construction and long-term costs of operations and maintenance. The objective is to make decisions that offer the lowest long-term cost for a given level of service, rather than targeting short-term savings (IPWEA 2006). Discounting is used to provide a common framework for costs incurred at different times. This practice serves the overall objective of minimizing the cost of delivering service at specified service levels (AMSA et al. 2002). Application of life-cycle costing has become a prominent feature of asset management programs in the UK and other nations.

In another industry, a similar approach is advocated by the Federal Highway Administration (FHWA), a branch of the U.S. Department of Transportation (USDOT). FHWA's Office of Asset Management has prepared a primer on Life-Cycle Cost Analysis, primarily directed at state departments of transportation (DOTs). FHWA acknowledges that life-cycle cost analysis has not yet become standard within state DOTs. Challenges to adopting this practice in the transportation environment have included a lack of understanding of the value of this practice, data limitations, and uncertainty related to both costs and engineering inputs (USDOT 2002).

FHWA has found that state agency staff are not well trained in handling uncertainty. Techniques are available, but staff are not familiar with them. This hampers full application of life-cycle cost analysis in practice.

FHWA's recommended approach also incorporates estimation of costs imposed on users of the transportation system; for example, when re-surfacing of roadways is needed. This element of the analysis is challenging in that values are difficult to estimate in monetary terms. In addition, state DOTs are reluctant to apply this part of the practice because it does not relate to their agency budgets.

It appears that North American water and wastewater utilities do not normally analyze full life-cycle costs in making infrastructure investment decisions. This is due, in part, to a desire to minimize short-term costs that affect customer rates or other revenue needs.

3.1.2 Application of Cost-Benefit Analysis

Cost-benefit analysis is a tool for answering broader questions about asset creation. Cost-benefit analysis seeks to determine whether the benefits of a project outweigh the costs; and which solution is best among a range of different types of solutions. Under the asset management paradigm, cost-benefit analysis includes structured consideration of risk (IPWEA 2006).

This tool stands in contrast to life-cycle cost analysis, which looks only at costs; and only at a narrow range of project alternatives with similar service-level characteristics. In addition, Cost-benefit analysis includes consideration of the costs and benefits to parties besides the agency and its customers. These are known as "externalities" (USDOT 2002). Use of the "triple bottom line" approach (see below) accounts for externalities.

Traditionally, water and wastewater utilities have used formal cost-benefit analysis only for the largest infrastructure decisions, such as building a dam and reservoir; a new wastewater treatment plant; or other projects with a very significant financial impact on the enterprise. Under full application of the asset management paradigm, this practice is applied to smaller projects as well, with efforts made to quantify costs and benefits. For example, one water utility requires all capital projects to be analyzed using cost-benefit analysis, with participation by a staff economist (SPU N.d). Cost-benefit analysis and life-cycle costing can also be applied to consideration of rehabilitation and replacement options, such as the various pipe renewal technologies available for a given project.

In order to make cost-benefit analysis practical for water and wastewater utilities, it would be valuable to have improved information on pipe renewal options. For example, it is important for the industry to develop well-documented information on the years a pipe's service can be extended by alternative improvement technologies. Does a cement lining extend pipe life by 20 years, or 80 years? Does a urethane lining last longer? Will a polyethylene slip lining provide a longer life, or raise problems by failing prematurely? Several AwwaRF projects are currently underway to address these types of issues for specific materials and techniques.

One variant of the asset management paradigm calls for systematic consideration of not only costs and benefits to the utility and its customers, but the broader costs and benefits for society as well as the environment. This has become known as the "triple bottom line," since it includes analysis of costs and benefits in three areas: financial, social and environmental (SPU N.d.).

In practice, North American utilities seldom quantify the social and environmental costs and benefits of project alternatives. This is due both to the lack of readily available values for social and environmental effects, and to the fact that these effects are external to the utility's bottom line. However, even a qualitative approach to identifying and describing non-financial costs and benefits can improve decision-making.

3.1.3 Asset Documentation

Under the asset management paradigm, documentation on new assets, such as vendor documents, as-builts and O&M manuals, CAD and standard specifications should be fully maintained and made accessible to operations and maintenance staff. This is not always a standard practice at many utilities.

3.2 OPERATIONS AND MAINTENANCE

One of the basic objectives of an asset management program is to provide desired service levels at the lowest possible life-cycle cost. Effective operations and maintenance (O&M) practices are critical to achieving this objective. Treatment plants, buried pipes, pump stations and buildings need to be maintained in order to achieve desired longevity, and risks of asset failure need to be managed using strategically targeted maintenance activities.

Maintenance practices under the asset management paradigm include some combination of the following elements (Fortin et al. N.d.):

- A well-planned maintenance strategy that takes account of risk factors and criticality of various system components to optimize the maintenance program. Balancing of preventive maintenance and reactive maintenance, according to this strategy.
- A system for scheduling, issuing and tracking work orders. For mid-size to large utilities, the use of a CMMS can increase productivity and provide timely access to asset data form management reporting.
- Condition and performance monitoring, with linkage to maintenance activity.
- Attention to metrics of maintenance work efficiency.
- Materials management and purchasing.

Each of these elements is discussed below, and current water and wastewater industry practices are compared with the asset management paradigm. However, condition and performance monitoring is addressed as a separate activity, in the following section of this White Paper.

Multiple studies have been conducted to analyze how well utility O&M practices conform to the asset management paradigm. A benchmark survey of 30 water and wastewater utilities focused on the relationship between asset management and O&M functional responsibilities to measure how the "average" utility complies with 60 industry-accepted best practices in asset management (Westin Engineering, Inc. 2006). Results of that survey concluded:

- High compliance (60% to 75%) with Best Practices in Asset Records (identification, hierarchies and prioritization), Work Orders (initiation through completion, reporting and histories) and Inventory (availability of identified spares for existing assets).
- Medium compliance (40% to 55%) with Function (recurring craft skill training and qualifications, workforce flexibility and succession planning), preventative maintenance/predictive maintenance (planning, scheduling, on-time completion and periodic updates) and Inspection (system operations and performance monitoring).
- Low compliance (0% to 25%) with Asset Financial Management (manpower and materials expensing, capital accounting and CIP planning and programming), Condition Assessment (planning and executing assessment and analyzing results), and R&R (strategic planning and programming for asset rehabilitation or replacement).

In another survey regarding maintenance management at 12 public water and wastewater utilities, it was found that utilities did well in areas of maintenance work orders, maintenance inventory/purchasing, and general maintenance practices. Areas where utilities scored the lowest were reliability engineering, maintenance reporting and predictive maintenance (Jennings et al. 2005).

These two surveys appear to support one another. U.S. utilities do a fairly good job in conducting day-to-day operations and maintenance (at whatever costs), while being less adept at some financial management functions and condition and performance monitoring. In addition, few utilities have formal programs for long-range strategic asset planning, rehabilitation, replacement or disposal rationalization and decision-making. Results of these surveys also seem to be borne out by a much more extensive survey conducted under the auspices of the international community (Buckland and Hastings 2001).

3.2.1 Development of Overall Maintenance Strategy

Multiple maintenance strategies are available and in use in various industries. These include Reliability-Centered Maintenance (RCM), Total Productive Maintenance (TPM), and Failure Mode Effect and Critical Analysis (FMECA) among others (Fortin et al. N.d.). In particular, RCM has received attention in recent years in terms of its applications to the water and wastewater industries under the asset management paradigm (Basson et al. 2006). RCM applies risk-management and predictive approaches to help plan maintenance activities. RCM can involve higher initial costs compared with other maintenance strategies, due to the need for technological tools, training, and establishment of baseline condition data. However, ongoing costs decrease as failures are prevented and preventive maintenance activity is replaced by condition monitoring. Overall, costs can be reduced through application of this strategy (NASA 2000).

Life-cycle costs can also be minimized, while still achieving service delivery objectives, by targeting more intensive maintenance to the most critical system elements. As such, a Run to Failure strategy is often appropriate for assets that have low criticality. This is in contrast to an approach wherein equipment overhauls are scheduled based on elapsed calendar days. This can inadvertently increase the overall failure rate or probability, due to the introduction of new parts or repair work into an otherwise stable system (NASA 2000).

At MWRA, application of RCM reportedly led to a 25% decrease in preventive maintenance work hours, largely by eliminating duplication of efforts between maintenance and operations staff at a large wastewater treatment plant. Preventive maintenance tasks were assigned to operations staff and could be addressed in normal daily rounds. There was also a focus on eliminating preventive maintenance to low value, non-critical equipment or intrusive actions that could inadvertently raise the risk of new equipment failures. In contrast, high value and critical preventive maintenance actions were identified and targeted for increased attention (Colbert et al. 2002).

Although RCM seems to be a well-known concept among utility O&M personnel, it is rarely used as an on-going strategy to enhance maintenance and asset management. Currently many organizations are reactive in nature. This is partly due to a perception that maintenance is an expense rather than an investment. This approach drives up the maintenance cost due to unplanned purchases and overtime expenses. A private sector survey showed maintenance practices to be 55% reactive, 31% preventive, 12% predictive and 2% other (Schultz and DiStefano N.d.). This contrasts with an ideal breakdown of less than 10% reactive, 25-35% preventive, 45-55% predictive and the balance proactive (Schultz and DiStefano N.d.).

For the most part, few utilities develop deliberate strategies for asset maintenance. The key gap appears to be developing an understanding among utility leadership of the purpose and viability of developing maintenance strategies.

3.2.2 System for Scheduling Work and Issuing Work Orders

Work orders contain highly valuable data on asset reliability, performance, condition and cost of ownership. It is therefore an essential part of asset management to have systems which allow work order entry, planning, scheduling and reporting. A computerized maintenance management system (CMMS) offers efficiencies that link operation and monitoring feedback to work orders, spare part warehousing and ordering, and other functions. As with other aspects of the asset management paradigm, an integrated approach offers opportunities to improve efficiency.

From experience, the majority of mid-size and large U.S. utilities now possess some form of automated or computerized maintenance management system (CMMS). However, use of the CMMS frequently does not correspond with the paradigm, since the automated applications are not used to their full extent to facilitate, record, and report work accomplishment and asset performance histories. Often the CMMS is used only as a record-keeping system to generate work orders. Assets are not uniquely identified or prioritized, nor are there established hierarchies to allow adequate cost accounting. There is limited attention to data quality and input control, thus filling the database with inaccurate information.

Research needs in this area should be directed toward first understanding why, despite wide-spread use of CMMS applications, they are generally not used to anywhere near their full potential to support maintenance and asset management. Then, once the reasons for lack of use are understood, further research would be needed to determine best methodologies for full implementation of automated aids in asset management.

Another challenge that occurs in maintenance of water and wastewater equipment is that the standard preventive maintenance recommendations of the original equipment manufacturer correspond poorly with maintenance needs under actual operating conditions. In many cases the manufacturer recommendations are overly protective. Improved recommendations for maintenance practices have been identified as a need in the industry (USGAO 2004; Fortin et al. N.d.).

An additional gap between actual practice and the asset management paradigm is that most utilities do not systematically assign criticality values to each asset, to prioritize resources directed at maintenance activities. This needs to be addressed in the utility's risk management framework.

3.2.3 Metrics of Maintenance Work Efficiency

In order to optimize maintenance programs, metrics are used to track the efficiency of maintenance activities and optimize maintenance performance. Trends in metrics then can be used to improve work processes in the asset management program. Metrics also assist in evaluating process changes in the maintenance arena, by providing data for before/after comparisons (Colbert et al. 2002).

For example, one wastewater utility uses metrics such as the percentage of preventive maintenance work orders that are kitted (needed parts assembled in advance), the percentage of predictive maintenance work orders and the percentage of preventive maintenance performed by operations (Fortin et al. N.d.). Other common metrics address maintenance costs, maintenance labor efficiency, and spare parts and materials (Moubray 1992).

In actual practice, maintenance metrics are rarely used. Although utilities often use other metrics to measure their performance, such as processing volumes and equipment run-time or downtime, measures of maintenance work efficiency or productivity are not often included among key performance indicators.

Closing the gap between actual practice and the asset management paradigm will require education of utility leaders on the value and necessity of maintenance performance goals and objectives. Then work can progress within utilities to define useful metrics within their organizations, implement the performance measurement system, and analyze the results.

3.2.4 Materials Management

Materials management plays an important role in the efficiency and effectiveness of the maintenance function. Materials that are improperly maintained cause equipment downtime and capacity losses. In fact, maintenance, repair, and overhaul of spare parts (MRO) accounts for an average of 50% of the maintenance budget. Therefore it is essential to develop and examine performance indicators that will ensure proper management of the inventory and procurement functions for maintenance (Wireman 2004).

A comprehensive asset management program will include a warehouse optimization plan that includes development and implementation of consistent and efficient warehouse activities in an effort to support maintenance, including spare part analysis, work order kitting, purchasing inventory replenishment, spare parts maintenance policies, and obsolescence of identified materials (Fortin et al. N.d.).

Spares and materials usually account for the portion of maintenance expenditures which does not come under the heading of "labor". How well spares and materials are managed is usually measured and analyzed in the following ways:

- Total expenditures on spares and materials (total and per unit of output)
- Total value of spares in stock

- Stock turns (total value of spares and materials divided by the total annual expenditure on these items)
- Service levels (percentage of requested stock items which are in stock at the time the request is made)

Due to cumbersome procurement procedures and delay in receipt, there is a tendency in water and wastewater utilities to over-purchase materials. This leads to unnecessary spending and larger space requirements. Additionally, when it comes to public entities, many are bound by low-bid laws and they are unable to create standard equipment specifications. The low-bid process sometimes results in the purchase of sub-standard spare parts resulting in more frequent failures. In addition, the inability to "spec" standard equipment results in a wide variety of spare parts increasing the stock holding requirements. Therefore, there appears to be a need to revise procurement standards in public utilities, especially since inventory has an annual carrying cost of 25-35% (Schultz and DiStefano N.d.).

Finally, there appears to be a struggle between which software system should be used to procure and track materials. While the maintenance team utilizes a CMMS for organizing its program, the procurement department typically will utilize an Enterprise Resource Planning (ERP) system to order parts. So, there can be a duplication of effort in accounting/reconciling leading to a need to streamline or integrate this process.

The increased use of materials metrics, and the adoption of a criticality framework to identify what critical spares are needed would help improve materials management element in comparison with the asset management paradigm.

3.3 CONDITION ASSESSMENT AND PERFORMANCE MONITORING

Monitoring the condition and performance of assets provides information needed to make decisions on maintenance and renewal. Issues in this area differ for buried assets and above-ground assets. While this topic is part of the Operations and Maintenance function, it is treated separately here due to its distinctive features as part of an asset management program.

3.3.1 Buried Assets

The most challenging area of condition and performance assessment involves buried assets, primarily pipes. At the same time, buried assets typically represent the largest infrastructure investment in water and wastewater systems (Allbee 2005).

Key inputs to managing pipes in an asset management framework typically include pipe age, size, material and repair history (Cromwell et al. 2001). Other attributes may include water quality data, hydraulic performance, soil type, and other planned construction projects (Mitchell et al. 2004).

Main break data has been identified as the most useful and available input to making decisions on pipe replacement and renewal. Data collection provides the opportunity to analyze trends, identify physical characteristics that correlate with breakage, and identify spatial patterns within the pipe network. However, pipe break data are not collected systematically at most utilities.

Predictive models utilizing break data to guide decisions on pipe rehabilitation and replacement are not well developed in the water and wastewater industries (Cromwell et al. 2001). Some utilities apply statistical models using large data sets to quantify the probability of pipe failure (WERF 2002). Failure curves can be developed for pipes of similar materials and sizes based on statistical analysis of main break data (Cromwell et al. 2001). Cromwell et al. argue that North American utilities should emulate their Australian counterparts by starting with available data and gradually improving data over time, rather than waiting to predict failure trends until data has been acquired or applying materials science to the problem of predicting failure rates (Cromwell et al. 2001).

Pipe condition assessment on the whole is often not done systematically, and is not well documented in utility databases (Cromwell et al. 2001, Deb, Grablutz, Hasit, Snyder, Loganathan and Agbenowski 2002). Large-diameter transmission mains are particularly problematic in terms of condition assessment. Non-destructive testing techniques are typically not available or cannot be readily implemented given the configuration of transmission mains. Therefore inspection and assessment is typically not performed until other circumstances require a transmission main to be taken off line. With the possible exception of reinforced concrete pipe, inspection of large mains while dewatered is not practiced.

Kleiner et al. (2005) identified a need for new, non-destructive testing techniques, and tools for using test data to generate condition ratings. They also identified "fuzzy-based modeling" as a technique that can improve failure prediction. This technique uses qualitative and subjective information gathered over time, in a systematic way to generate expected trends in pipe condition. However, they also found that historical data is often not available to apply this technique for large transmission mains.

Perhaps the most important factor in determining the level and type of effort needed in condition assessment is the potential consequence of pipe failure, for different pipes in the system (Makar and Kleiner 2002). This points to the application of risk assessment techniques even in guiding condition assessment data collection. Some other examples of approaches used in recent years to aid in prioritizing main renewals include:

- An asset management tool developed by a European consortium for sewer and water pipelines called CARE-S and CARE-W, respectively. The CARE-W model uses a cohort analysis of pipe breaks for prioritizing mains for renewal.
- One large North American utility is exploring a very different approach to pipeline maintenance, using continuous leak monitoring of pipelines. In a pilot program there has been a shift in cost-benefit of main replacement of an aging water system, due to leak detection occurring very soon after leaks occur. This lowers the cost of repairs, the risks of damage and the cost of water losses. The reduced consequence of failure permits extended utilization of pipe life. In addition this practice generates improved data for planning of future renewal needs (Hughes 2006b).

Given this information, the biggest gaps in the area of condition assessment for buried pipes appear to be in systematically collecting and organizing data, and using formal risk assessment methods to prioritize resources for both condition monitoring and renewal actions. In addition, there is a need for improved inspection and condition evaluation technologies. Finally, effective application of these techniques requires training of utility staff.

3.3.2 Above-Ground Assets

Above-ground assets encompass a wide range of equipment and infrastructure, such as buildings, storage tanks, above-ground pipelines, pump stations and water and wastewater treatment plants. Inspection is obviously more easily performed for above-ground assets compared with buried assets. Nonetheless, attention on performance monitoring approaches is warranted, particularly for operating equipment.

One recent AwwaRF study developed tools for assessing the physical condition and operating characteristics of water treatment plants (Elliott et al. 2003). This assessment contributes to prioritization of components needing improvement.

Condition monitoring techniques for operating equipment can include oils analysis, vibration monitoring, infrared, ultrasonic, and motor current signature analysis (Fortin et al. N.d.). While these processes are well developed, they are not well known or implemented throughout the water and wastewater industries.

Failure Modes and Effects Analysis (FMEA) offers a tool for prioritizing condition assessment of above-ground assets (Anwar et al. 2005). Under this approach a risk-based approach is applied that takes into account both the probability and consequences of asset failure. Expenditures on condition assessment are limited to assets for which the cost of failure exceeds the costs of renewal. One advantage is that this approach takes into account causes of failure that are not due to asset condition.

3.4 ASSET RENEWAL (REHABILITATION AND REPLACEMENT)

One of the primary drivers of asset management practices in North America is the deterioration of existing infrastructure that was installed decades ago. Various reports (USEPA 2002, WIN 2000) have called attention to the national scale of this problem and the very large price tag for renewing water and wastewater infrastructure. Similarly, utility counterparts overseas have recognized this problem, with the well-known “Nessie curve” providing a graphic illustration of the concept.

Perhaps the greatest potential for applying asset management in North America is in managing the financial burdens associated with infrastructure renewal. The value of the asset management framework is in prioritizing expenditures using techniques of risk assessment and investment optimization. These techniques are most powerful when applied in a systematic and rigorous fashion. The asset management paradigm seeks to achieve this.

This component of the asset management paradigm includes:

- Strategic decision-making on asset renewal strategies based on the varying risk and criticality attributes of specific assets
- Comparison of the cost of continued maintenance and repair expenditures versus the cost of projects to rehabilitate or replace assets
- Choice of rehabilitation and replacement technology

Application of these techniques has much in common with the asset creation/acquisition process. This includes careful application of life-cycle cost analysis and cost-benefit analysis, as discussed previously in this White Paper. In addition, the renewal analysis draws on information from condition and assessment monitoring, also discussed previously.

3.4.1 Risk and Criticality

Risk can be considered using two basic components: the probability an event will occur and the consequences of that event (Harlow and Buckland 2005).

In practice, water and wastewater utilities do not use risk assessment formally or consistently in making asset decisions. Some argue this is due to lack of understanding on how risk should be analyzed as well as the lack of simple practical tools for risk assessment in the water and wastewater industries. Without these tools, utilities are also unsure about what kind of data should be collected to support a risk assessment approach (Harlow and Buckland 2005).

3.4.2 Cost Comparisons

In simple terms, economic life is defined by the point when an asset begins to cost more to operate and maintain than to replace (Hughes 2006a). Since economic life is defined in part by the comparison to replacement alternatives, definition of replacement alternatives is a key element in decision-making (Buckland and Hastings 2001).

Risk can be incorporated in the calculation of economic life. When this is done, high consequence assets will be found to have a shorter economic life than low-consequence assets (Buckland and Hastings 2001). In other words, high consequence assets should be replaced sooner, because the costs of failure are high. Therefore, the risk and criticality assessment described previously provides important inputs to the cost comparison for renewal decisions.

For example, risk models are available that use a weighted score approach to identify critical pipes for rehabilitation or replacement. Scoring is based on factors such as leak history, pipe size, pressure, age-damage potential, soil corrosivity and consequence of failure. This can be done using simple spreadsheets or sophisticated database programs (Grigg and Blaha 2005).

In comparing costs between replacement and rehabilitation alternatives, it is important to also identify and compare benefits. Replacement alternatives may provide opportunities to add capacity to the system and improve service levels beyond what is achievable through rehabilitation projects (Ambrose and Habibian 2002).

Traffic disruptions and related social and environmental impacts and costs are often not included in the estimated cost of engineering projects (Grigg and Blaha 2005).

Choice of discount rate affects the outcome of decisions that rely on cost comparisons. Many utilities lack the skills in economic analysis that would allow them to make sophisticated choices about the discount rate for a given project. Lacking this capability, they typically rely on sensitivity analysis of discount rate levels, if they do any analysis at all.

Cromwell et al. (2001) argue that most North American utilities have not yet defined an "objective function" as the basis for main replacement programs. In contrast, this has been done in Australia and other countries, where the objective function is defined to minimize the cost over time of various interventions such as monitoring pipe conditions, repairing pipes, extending pipe life and replacing pipes.

3.4.3 Renewal Technologies

Improved technology for extending the life of existing infrastructure can help to flatten utilities' infrastructure cost curve over the coming decades (Hughes 2006a). Techniques for rehabilitating aging pipes include flushing, cleaning and relining. Several AwwaRF reports have been prepared to address these techniques (Grigg and Blaha 2005). In addition the industry has increasingly become aware of trenchless technologies such as pipe bursting and slip lining (Grigg and Blaha 2005).

3.5 ASSET DISPOSAL

For underground assets, asset disposal is not given much consideration when renewal is implemented. Old pipe material is typically left in the ground as new pipe is installed.

The literature review did not suggest utilities face significant challenges in this stage of the asset life-cycle. However, it is possible that public health and safety issues will arise with eventual decommissioning of pipes containing asbestos.

It is not apparent whether utilities are proactively planning for asset disposal cost. This topic can be addressed further through discussion at the upcoming workshop.

4.0 RECENT WORKSHOPS ON ASSET MANAGEMENT NEEDS

Several major workshops have been held since 2002 to address needs for further development of asset management in the water industry, wastewater industry or both. This section summarizes the recommendations of these prior workshops, particularly those related to research.

4.1 ADVANCED ASSET MANAGEMENT COLLABORATIVE WORKING SESSION (2005)

Sponsored by the United States Environmental Protection Agency (USEPA), this workshop brought together approximately 140 individuals from both the water and wastewater industries for a two-day event designed to advance asset management in the United States. The objective was to develop a three- to five-year action agenda for "the advancement of asset management practices in the water industry [including wastewater] and in state and local government."

USEPA reports that "the single most prevalent theme … appears to be that of 'knowledge transfer' – the effective and efficient accumulation, organization and dissemination of 'best practices' regarding asset management concepts, processes and practices relevant to the U.S. management culture" (USEPA 2005).

The workshop included breakout sessions to generate recommended actions in four separate categories: the water industry, educational trainers including universities and professional organizations, research agencies (professional and academic) and government institutions. In the research category, the top ten actions recommended were:

- Development of a central depository of high quality data available to researchers
- Standard methods for comprehensive benefits analysis
- Tools/techniques to incorporate sustainability into asset management (specific) ecological footprint and quantification of non-economic impacts
- Develop common/best practices for risk management framework
- Dictionary of uniform/standard/granularity terms for cross dependencies (classifications, activities, metrics, cost models) – for all types of systems
- Models for cross asset management function interdependencies/knowledge management integrated asset management/public perception
- Research on tools for cost-effective physical conditions assessment including design standards – non-invasive, non-destructive, cost-effective
- Define important/priority cornerstones/vision of asset management
- Maintenance-focused definition of maintenance cost standards
- Definition of engineering curriculums consistent with asset management philosophy

Using a voting process, participants at the workshop ranked actions generated in all four breakout sessions to identify the overall top ten actions. These ten actions are shown below, and include three items (Items 3, 6, and 8) from the research breakout session:

1. Best practices
2. Defining asset management; building business cases

3. Development of a central depository of high quality data available to researchers
4. Develop an international training and resources clearinghouse
5. Level of service/asset management business model
6. Research on tools for cost-effective physical conditions assessment including design standards
7. Develop uniform national standards for condition assessment and asset reporting
8. Develop common/best practices for risk management framework
9. Asset management plans be made requirements for any government funding
10. Culture change

4.2 GLOBAL WATER RESEARCH COALITION RESEARCH STRATEGY WORKSHOP (2005)

The Global Water Research Coalition is a group of several water industry research organizations from North America, Europe, United Kingdom, Australia, and South Africa. Both AwwaRF and WERF are members. The organization held a workshop in 2005 to address research priorities related to asset management. The workshop was scheduled to occur the same week as the USEPA workshop discussed above, and some participants attended both events.

One theme evident in the available summary of this event is that asset management is in its infancy internationally, and different approaches are being developed in different countries. Some workshop participants were concerned that duplication and/or an inability to transfer knowledge from one national context to another could result if different countries proceed on different tracks. Therefore, the workshop participants saw value in international standardization to produce common programs and foster collaboration.

GWRC identified seven projects as priorities for research (UKWIR 2005). These are listed below.

1. Development of a framework for asset management.
2. Process mapping of asset management.
3. Best Practice case studies and documentation.
4. Methodology for cost and benefit valuation in asset management decision support.
5. Data Requirements for strategic asset management decision-making.
6. Tool for Risk Management.
7. Review of Technology used in strategic asset management.

GWRC also identified predictive models and data requirements for correlating asset condition and performance of above-ground assets as a valuable area for knowledge improvement.

In July 2006 GWRC held a follow-up meeting to report on follow-up discussions within the individual GWRC member organizations. From the seven recommendations listed above, Items 1 and 2 will not be developed as formal projects, but GWRC members will continue to collaborate informally in sharing information on asset management frameworks and processes. The remaining five projects were identified for further project development, and GWRC member organizations were tentatively designated to take lead roles on each of them. For example, it was suggested AwwaRF lead Item 5. WERF, UKWIR and EPA were identified for other activities. However, further action on these items will require further internal review and action by management and governing boards of the respective organizations.

4.3 WATER ENVIRONMENT RESEARCH FOUNDATION WORKSHOP: RESEARCH PRIORITIES FOR SUCCESSFUL ASSET MANAGEMENT (2002)

The Water Environment Research Foundation (WERF) held a similar workshop in 2002. This workshop included attention to both the water and wastewater industries in North America.

One exercise at this workshop was an assessment of the degree to which various asset management tools function as needed for effective asset management implementation (WERF 2002). Participants ranked the following tools low in terms of their availability, accessibility, usefulness, cost and other criteria:

Condition assessment methods
Modeling condition versus performance
Integrating O&M
Optimizing O&M programs
Documenting maintenance
Predicting future condition and useful life
Quantifying risk
Assessing risk versus asset condition
Evaluating alternative R&R programs
Calculating life-cycle costs
Projecting capital and operating costs
Calculating revenue needs and rates
Reporting to GASB standards
Database integration
Database management

Eleven projects were recommended for funding by WERF, as follows (WERF 2002).

1. Develop protocols for assessing the condition and performance of water and wastewater infrastructure assets and develop predictive models for correlating asset condition and performance.
2. Construct predictive life-cycle models for water and wastewater infrastructure that project life-cycle costs and risks.
3. Construct a template for preparing infrastructure asset management plans.
4. Prepare guidance for asset management strategic planning.
5. Develop practical methodologies for calculating life-cycle costs for water and wastewater infrastructure assets.
6. Document case studies of improved customer service and satisfaction and reduced costs as a result of implementing asset management.
7. Identify O&M best practices by asset category, condition and performance requirements.
8. Define best practices for the integration of water and wastewater databases.
9. Establish methodologies for determining water and wastewater asset value, compiling asset inventories and capturing and compiling asset attribute information.
10. Develop a framework for asset management accountability.
11. Assess the feasibility of establishing an Asset Management Standards Board for the water and wastewater industries.

Since 2002, many of the projects listed above have been addressed by WERF. Others have been identified for attention between 2006 and 2010. The following section contains information on recent and ongoing WERF project activity that addresses these topics.

4.4 RESEARCH FORESIGHT PARTNERSHIP, UNDERGROUND ASSETS RESEARCH NEEDS (2005)

In the UK the Research Foresight Partnership is managed by WRc on behalf of six water and wastewater utility companies. The Partnership has initiated a series of workshops covering a range of issues and aimed at developing a research agenda (Conroy and Walker 2005). The first workshop, held in August 2005, covered research needs related to underground assets. The workshop results are intended for further discussion by the Partners, prior to selection of projects and definition of research budgets. Results include attention to:

1. Locating, recording and mapping buried assets.
2. Development of "lead" (advance) deterioration indicators and appropriate data collection.
3. Improvement of acoustic methods for leak detection, and data collection on leakage quantification supporting these methods.
4. Technologies including micro-sensors for leak detection.
5. Internal inspection systems for large mains, including potential research on robotic systems.
6. Application of water quality monitoring to assessment of condition of large mains.
7. Improved understanding and definitions of asset risk including attention to data collection.
8. Research on long-term performance of plastic pipes and joints.

5.0 AREAS OF RESEARCH CURRENTLY FUNDED BY AwwaRF AND SIMILAR ORGANIZATIONS

AwwaRF and similar organizations such as WERF, UKWIR and CSIRO have actively supported research into a number of asset management topics in recent years. In another industry, the Electric Power Research Institute (EPRI) has an active research program on asset management. Review of projects recently completed or underway can help in shaping AwwaRF's strategy for new research funding.

5.1 Awwa RESEARCH FOUNDATION (AwwaRF)

AwwaRF has actively funded research in asset management practices for many years. Appendix A-1 provides a list of 47 projects that have been completed and an additional 18 projects underway at this time. These projects have covered a wide variety of subject matter, including items that fall into both the "programmatic" and "life-cycle" categories described in this White Paper. Several of these projects include development of decision-support software, in addition to published reports.

In the area of programs and policies for asset management, AwwaRF-funded research has examined topics such as risk management, customer preferences, utility planning and reporting, performance indicators, costs of infrastructure failure, and GIS technologies and costs.

In the area of condition and performance assessment, projects have been funded to explore condition assessment of water mains; predicting performance of PVC, ductile iron, and polyethylene pipe; non-destructive evaluation techniques for pre-stressed concrete pipe and other materials; and leak detection methods.

Research topics under repair, rehabilitation and replacement have included techniques for locating buried infrastructure, in situ epoxy lining, well rehabilitation, project prioritization and financial optimization of renewal programs. Reliability centered maintenance for water systems has also been studied.

Section 6 of this report provides additional information on asset management research needs and topics that have been studied in AwwaRF research projects, broken down by specific topics.

5.2 WATER ENVIRONMENT RESEARCH FOUNDATION (WERF)

In the four years since the WERF 2002 workshop described previously, WERF has funded additional research and related activity intended to address many of the items identified at the workshop. Further work is planned between 2006 and 2010. Based on information provided by WERF staff (Ramani 2006), the following summarizes WERF activities that have been either completed or are being launched at this time:

- WERF has led development of a Web site on asset management known as the Sustainable Infrastructure Management Program Learning Environment, or SIMPLE. Developed from a pre-existing Asset Management Program Learning Environment (AMPLE) platform by GHD, this product is based on asset management practices used in Australia and New Zealand, but has been re-shaped to fit the U.S. wastewater industry. WERF provides SIMPLE at no cost to its subscribers. Further activity is planned for 2007-2010 to add more content to SIMPLE. This includes plans, funded by AwwaRF, to add content aimed at water utilities in 2007. (GHD In Progress).

- WERF and AwwaRF co-funded an ongoing project to be completed in 2007 called "Condition Assessment Strategies and Protocols for Water and Wastewater Utility Assets" (Marlow et al. 2007). Phase I of the project is complete and involved a survey of utilities, a literature review and production of a partial summary of condition assessment tools available in the water and wastewater industries. Phase II is underway and involves case studies of participating utilities and refinement of information on condition assessment tools and techniques, as well as exploration of how Web-based tools could be used to improve utilities' ability to select the right tools for their specific circumstances. One finding of this project is that "the framework for condition assessment – i.e., why and where condition assessment should be done, and how individual assets should be selected for condition assessment – needs to be addressed in order to properly assist utilities in selecting appropriate tools and techniques for performing condition assessment. This way the appropriate tools can be matched to the business objectives of the utility"
- As of October 2006 WERF was launching a "Challenge" for Strategic Asset Management Communication and Implementation. The project statement indicates it is to "Develop Guidance and Decision Support Tools for Communicating and Implementing a Strategic Asset Management Program (SAM) for Wastewater (and possibly water) Facilities and Estimating Assets' Performance and their Residual Economic Life" (WERF 2006). This Challenge has three interrelated components that are under consideration and will be developed further as a contractor is retained. These elements include:
    - Strategic asset management/communication package and analytic tools for startup and implementation. This element responds to the fact that different utilities are at different stages of adopting and implementing asset management practices, and differing local contexts lead to different approaches.
    - Establishment of a Web-based database for compiling information on case studies, best practices, benchmarking, lessons learned, processes and methods related to strategic asset management.
    - Development of protocols and methods for predicting the remaining economic life of utility assets.

WERF staff have indicated that most of the 11 recommendations from their 2002 workshop have been addressed through this series of completed, ongoing and upcoming projects; or through work being done collaboratively by other members of the GWRC, including AwwaRF.

5.3 NATIONAL RESEARCH COUNCIL - CANADA (NRC)

Canada's National Research Council (NRC) has funded various studies and publications on asset management and buried infrastructure. Topics have included tools and techniques of asset management (Vanier 2000), investment planning for municipal infrastructure (Vanier 1998, NRC Canada 2005), maintenance management (Hassanain et al. 2003), and indicators and benchmarks (National Guide to Sustainable Municipal Infrastructure 2002). Detailed research on modeling and predicting failure of buried pipes and management and decision processes for maintaining buried pipes has also been carried out by NRC researchers (Kleiner et al. 2005; Kleiner and Rajani 2002; Makar and Kleiner 2002; Kleiner and Rajani 1997).

5.4 BURIED ASSET MANAGEMENT INSTITUTE (BAMI)

BAMI was formed in 2003 as a part of the City of Atlanta's Department of Watershed Management, with the intent of revamping the City's approach to management of its wastewater collection system. In 2005 it was converted into a non-profit organization. Its primary project at this time is an EPA-funded project to conceptualize a national "Center of Excellence" addressing management of both buried and above-ground, water and wastewater assets. The purpose of the project is to define what such a center would do and how it could be supported institutionally (Iseley 2006).

5.5 ELECTRIC POWER RESEARCH INSTITUTE (EPRI)

EPRI has an active program of research on asset management for the power industry, with elements addressing power delivery systems, nuclear generation, and enterprise asset management. Information on its research program was gathered through an interview with EPRI staff (Bloom 2006) and review of EPRI's Web site (www.epri.com). It has developed a series of guidebooks related to asset management. While directed at power industry professionals, many of the concepts and procedures may be transferable to the water and wastewater industries.

One element that has been presented in EPRI's guidebook series is a process model that identifies business processes in an asset management framework, as compared with traditional organizational structure. The intent was to develop a process model that could be widely adapted by different types of organizations in the power industry, both public and private. One element of the model is the breakdown of functions into categories identified as the "asset owner," "asset manager," and "service provider." This breakdown facilitates overcoming organizational silos in decision-making.

In 2006, EPRI directed research attention on the relationship between asset management and long-range planning. This included attention to two problems that commonly arise in the power industry:

1. Expansion of the power delivery infrastructure to serve new customers is seen as more critical than maintenance, leading to under-funding of maintenance; and
2. The power industry has a lot of aging infrastructure nearing the end of its lifetime. Analytical tools are being examined to make optimal decisions on replacement using sound economic principles.

On the latter topic, one area of research is to develop improved tools for predicting failure of underground cables and other buried assets.

Another area of research involves determining budget priorities among many projects that affect different issues. This involves developing a common valuation framework, using principles of risk management. This can be applied either within a functional category, such as power generation or distribution; and also across functions. The valuation model needs to account for different types of value, such as reliability, safety, environmental protection, and revenue. It also needs to be operational so that staff engineers proposing projects can apply the model.

One recently developed product is a software tool for project prioritization (P2).

EPRI also has carried out research related to application of information technology to work order generation and other functions; techniques for integrating databases using a Common Information Model (CIM); and automation of data collection on field equipment for use in failure analysis and prediction.

5.6 ORGANIZATIONS OUTSIDE NORTH AMERICA

Organizations such as United Kingdom Water Industry Research Limited (UKWIR), Commonwealth Science and Industrial Research Organization (CSIRO) in Australia, and Collective Research of the Netherlands Water Industry (Kiwa) have been active in funding additional research. There has been ongoing contact among AwwaRF, WERF and these organizations abroad regarding research collaboration on asset management topics. The Global Water Research Coalition (GWRC) provides a forum for discussion and agreement on collaborative projects.

A GWRC review of asset management research priorities (Kirby 2005) identified a number of projects underway outside North America as of 2004. Among others, these include the CARE-S and CARE-W projects. The European 5th Framework is funding a project with participation by 11 nations on Computer Aided Rehabilitation of Sewer Networks (a.k.a. CARE-S). Different models of classifying and assessing sewer condition will be analyzed and tested, using CCTV data from sewer utilities. The project aims to develop models for forecasting when a sewer line will reach a defined threshold necessitating either inspection or rehabilitation. A similar model for water systems (CARE-W) is also under development.

In the UK the Research Foresight Partnership is managed by WRc on behalf of six water and wastewater utility companies. The Partnership has initiated a series of workshops covering a range of issues and aimed at developing a research agenda. The first workshop, held in August 2005, covered research needs related to underground assets. The workshop results are intended for further discussion by the Partners, prior to selection of projects and definition of research budgets. The results include attention to locating, recording and mapping buried assets; development of "lead" (advance) deterioration indicators and appropriate data collection; improvement of acoustic methods for leak detection, and data collection on leakage quantification. They also include technologies including micro-sensors for leak detection; internal inspection systems including potential research on robotic systems for large mains; application of water quality monitoring to assessment of large mains; improved understanding and definitions of asset risk including attention to data collection; and research on long-term performance of plastic pipes and joints (Conroy and Walker 2005).

UKWIR has recently developed a protocol for data collection and reporting on main failures; together with a database recording this information from a sample of water companies. This information is designed to improve understanding of trends in main failures and management of capital expenditures in this area. The project has also highlighted gaps in data and areas where improvement of data quality are needed (MacKellar and Pearson 2003).

In Australia, the Water Services Association of Australia (WSAA), National Water Commission (NWC) and parties to the National Water Initiative (NWI) recently developed a National Performance Framework that provides performance indicators and detailed definitions (WSAA et al. 2006). These can offer useful "benchmarks" for utilities in North America, either for developing performance indicators within a utility, or as a basis for comparison with other utilities. Examples of the performance indicators listed include the number of main breaks annually per kilometer of pipe; the number of customers (properties) affected by supply interruptions per 1,000 customers served; duration of unplanned service interruptions, water losses, and number of customer complaints, among many others.

6.0 SUMMARY OF NEEDS AND OPPORTUNITIES

The review of industry experiences as documented in the published literature, coupled with results of recent workshops on the subject of asset management allows identification of a range of needs and gaps facing the North American water and wastewater industries.

This section highlights the primary gaps identified, and groups them according to the following categories:

- Category 1: Gaps in knowledge transfer, in that the information and techniques are available but have not been widely disseminated to utility managers and staff involved in infrastructure-related decision-making. The remedy for this category is training programs and production of Web-based or published information designed to be accessible to the full range of practitioners in the industry. Initial efforts in this direction will particularly benefit utilities that are just beginning to develop asset management programs. Because application of the asset management paradigm is in its infancy in North America, that describes the vast majority of utilities.
- Category 2: Gaps in the "tools" of asset management, such as analytical techniques or effective software. The remedy for this type of need is development and pilot testing of practical tools applicable in the water and wastewater context. While this approach can benefit the entire industry, the utilities who can immediately put this type of information to use are those who are actively developing or already implementing asset management programs and need ways to improve on the basic framework.
- Category 3: Gaps in scientific or technical information and understanding. Scientific and technical research is needed to remedy gaps of this nature. As with Category 2, this can benefit the entire industry but offers the greatest value to utilities that are already developing or implementing comprehensive asset management programs. Once the basic framework and analytical tools have been put into place, new science can be used to refine and optimize risk assessment, economic analysis and resulting decision-making.

Table 6.1
Comparison of Industry Needs with Current/Upcoming Activity

Identified Needs	Current/Ongoing Activity Addressing Similar Needs
1. EDUCATION AND TRAINING	
Overall Education and Training Resources	
Fundamental terminology, definitions, and practical approaches to asset management, including "best practices" and template materials Web-based access to available guidance manuals and other literature on tools and techniques, applicable to various stages of asset management program development	▪ *International Infrastructure Management Manual* (IPWEA 2006). ▪ SIMPLE Web site, created by WERF with USEPA funding. SIMPLE is being expanded to include drinking water in 2007 with AwwaRF funding. (NRC Canada In Progress (b)) ▪ WERF research starting up 2007 (WERF 2006) ▪ BAMI and Pennsylvania State University activity funded by EPA to develop Web-based educational tools and conceptualize a "national center of excellence" of asset management in the water and wastewater industries.
Case studies demonstrating benefits of asset management approach, in terms of controlling costs and meeting service objectives	▪ Literature contains case studies (e.g., Matichich et al. 2006b, HDR Engineering, Inc. In Progress (a) among many other publications).
Development of engineering curriculum materials on asset management (undergraduate, graduate, continuing educ.)	
Organizational Structure and Program Management	
Human resource needs for effective implementation of asset management	▪ Literature on organizational change from the business community.
Management techniques supporting cultural changes, including leadership and team building strategies	▪ AwwaRF's *Developing a Risk Management Culture, Mindfulness in the International Water Utility Sector* (Cranfield University In Progress). ▪ WERF research starting up 2007 (WERF 2006)
Advocacy for asset management, with customers, stakeholders and elected boards	▪ *Water Infrastructure at a Turning Point: The Road to Sustainable Asset Management* (Hughes 2006a).
Document control/coordination between engineering and construction to support O&M and asset management program	
Cost-Benefit Analysis	
Training on cost-benefit analysis	▪ GWRC project (WERF In Progress). See overall education and training resources, above.
Training on life-cycle cost analysis	▪ See overall education and training resources, above.
Training on quantifying social costs	▪ See overall education and training resources, above.
Risk Management	
Training on quantifying risk of failure in economic framework, including probability/consequence models.	▪ GWRC project (UKWIR, In Progress (a)).
Financial Management	
Financial management protocols supporting full funding of future renewal needs	▪ See overall education and training resources, above. ▪ *Asset Management Planning and Reporting Options for Water Utilities* (Matichich et al. 2006).
Data Creation and Data Management	
Training on database integration	▪ USDOT Primer on data integration for transportation agencies (USDOT 2001).
Depreciation and life-cycle	(Continued)

Table 6.1 (continued)

Identified Needs	Current/Ongoing Activity Addressing Similar Needs
Operations & Maintenance	▪ See overall education and training resources, above.
Identify O&M best practices by asset category, condition and performance requirements, including above-ground and buried assets	▪ See overall education and training resources, above.
Customer Service Levels	
Case studies of improved customer service and satisfaction and reduced costs from asset management programs	
Equating customer service performance indicators into cost-benefit analysis	▪ Part of GWRC proposed research area (UKWIR 2005).
2. MANAGEMENT TOOLS	
Asset Management Framework	
Development of a framework for asset management, including vision and cornerstones	▪ AwwaRF research : *Asset Management Planning and Reporting Options for Water Utilities* (Matichich et al. 2006) ▪ *International Infrastructure Management Manual* (IPWEA 2006).
Process mapping of asset management	
Benchmarks consisting of well-defined performance metrics to be used within a utility or across utilities	▪ Australian's *National Performance Framework* (WSAA et al. 2006) ▪ *Performance Indicators for Water Supply Services* (Alegre et al., 2006)
Define a framework for utilities to adopt an Environmental Management System approach to asset management	
Assess the feasibility of establishing an asset management standards board	
Estimated cost of implementing comprehensive asset management programs, and return on investment	
GAP analysis approaches applicable to North America	
Extraction of tools and techniques from similar industries such as electrical power transportation, aviation and oil and gas (Matichich et al. 2006, USGAO 2004)	
Organizational Structure and Program Management	
Approaches to managing culture change in support of asset management	▪ Literature on organizational change from the business community.
Organizational models that support asset management practices	
Cost-Benefit Analysis	
Standard methods for comprehensive benefits analysis, including quantification of non-economic impacts such as indirect social consequences of pipe failure	▪ AwwaRF funded project that developed ways to estimate costs of infrastructure failures including indirect costs (Cromwell et al. 2002). ▪ WERF will lead a GWRC project to improve methodologies of cost and benefit valuation for asset management, with support by AwwaRF and UKWIR (WERF In Progress). ▪ USDOT primer on economic analysis for transportation departments (USDOT 2003)
Tools/techniques to incorporate sustainability into asset management	
Triple bottom line methodology	▪ AwwaRF study on triple bottom line decision-making and reporting (Kenway et al. 2007)
Practical methodologies for calculating life-cycle costs of water and wastewater infrastructure assets, including risk considerations	▪ USDOT primer on life-cycle cost analysis for transportation departments (USDOT 2002).
Techniques for optimization of tradeoffs between capital investments and operating expenses	AwwaRF is soliciting proposals in 2007 for Setting Water Utility Investment Priorities: Assessing Customer Preferences and Willingness to Pay (University of New Mexico In Progress).

Continued

Table 6.1 (continued)

Identified Needs	Current/Ongoing Activity Addressing Similar Needs
Risk Management	
Risk assessment and risk management techniques including rating systems based on criticality, consequence, and risk tolerance levels	▪ AwwaRF projects: estimating costs of infrastructure failure (Cromwell 2002); *Customer Acceptance of Water Main Structural Reliability* (Damodaran et al. 2005); *Estimating Health Risks from Infrastructure Failure* (Emde et al. 2006); *Risk Management of Large Diameter Water Mains* (Kleiner et al. 2005); *Risk Analysis Strategies for More Credible and Defensible Decisions* (Pollard et al. 2007); and *Developing a Risk Management Culture - Mindfulness in the International Water Sector* (Cranfield In Progress). ▪ UKWIR is leading a GWRC project, with funding by AwwaRF, WERF and WSAA, on risk management for asset managers of water utilities. (UKWIR In Progress (a)). ▪ Electric Power Research Institute research projects in asset management of power delivery systems.
Financial Management	
Develop valuation and depreciation guidelines for water and wastewater assets	Check with the American Society for Testing & Materials (ASTM).
Develop ability to project short- and long-term financial impacts of infrastructure rehabilitation and replacement needs	
Develop improved financial reporting protocols	▪ *Asset Management Planning and Reporting Options for Water Utilities* (Matichich et al. 2006b)
Data Creation and Data Management	
Develop data frameworks such that multiple data systems within utilities (SCADA, GIS, CMMS, Financial Systems, etc.) support enterprise-wide asset management program	▪ AwwaRF is soliciting proposals for a workshop project on Optimizing Information Technology Solutions for Water Utilities (Red Oak Consulting In Progress)
Develop guidelines for practitioners to determine what and how data needs to be collected, structured and numbered for compiling asset inventories	▪ GWRC, with AwwaRF as lead, will be soliciting proposals in 2007 for a project on details of condition assessment data (AwwaRF In Progress). ▪ NSF grant: Sustainable Water Infrastructure Management System (SWIMS). Data needs and availability, supporting decisions on maintenance, repair and renewal for piping systems. (NSF 2007).
Operations and Maintenance	
O&M performance indicators and measures; effectiveness of alternative performance management systems	▪ AwwaRF's *Selection and Definition of Performance Indicators for Water and Wastewater Utilities* (Crotty 2003)
Maintenance spending benchmarks	
Requirements and benefits of maintenance planning and scheduling	▪ AwwaRF's *Applicability of Reliability-Centered Maintenance in the Water Industry* (Basson et al. 2006)
Materials procurement and management practices	
Maintenance-focused definition of maintenance cost standards	
Condition Assessment	
Economics of condition assessment and prioritization	
Customer Service Levels	
Improved linkage of asset-management decisions to customer service levels. Techniques to evaluate the benefits of differing service level, including customer willingness to pay for differing service levels	▪ AwwaRF: *Customer Acceptance of Water Main Structural Reliability* (Damodaran et al. 2005)
Consideration of how the U.S. regulatory system supports or prevents prioritization by accounting for customer service levels.	(Continued)

Table 6.1 (continued)

Identified Needs	Current/Ongoing Activity Addressing Similar Needs
Engineering Design	
Design standards	
Designing equipment with greater emphasis on reliability, maintainability and application of new tools/techniques of asset management programs	
Decision Support Systems	
Life-cycle cost models of various materials/equipment	
Computerized decision-support systems	▪ AwwaRF's *Decision Support System for Distribution System Piping Renewal* (Deb, Hasit, Schoser, Snyder, Loganathan and Khambhammettu 2002)
3. PHYSICAL SCIENCE AND TECHNOLOGY	
Location of Buried Pipes	
Improved technologies for locating buried pipes, including ground-penetrating radar	▪ AwwaRF's report on *New Techniques for Precisely Locating Buried Infrastructure* (Deb et al. 2001). ▪ Review of ground penetrating radar and other locating technologies in AwwaRF-GTI project (Gas Technology Institute In Progress (a)) ▪ UKWIR's *Multi-utility Buried Pipes and Appurtenances Location Workshop* (Overton 2002) – available to AwwaRF subscribers
Condition Assessment	
Improved, cost-effective techniques and technologies for condition assessment of buried pipes including distribution pipes and large-diameter transmission lines; predictive models for correlation of condition and performance.	▪ AwwaRF projects in recent years have addressed condition assessment of water mains (Lillie et al. 2004), pipe joints (Reed et al. 2006), monitoring of structural behavior of pipelines (Reed et al. 2004), electromagnetic inspection of PCCP (Megelas and Kong 2001), leak detection (Hunaidi et al. 1999, Gas Technology Institute In Progress (a)), performance and cost targets for inspection (PB Americas, Inc. In Progress), protocols for assessment of condition and performance (Marlow et al. 2007), condition assessment of service lines, connections and fittings (Le Gouellec and Cromwell 2007), assessment of water treatment plant facilities (Elliot et al. 2003) and related topics. ▪ AwwaRF / WERF funded project, *Condition Assessment Strategies and Protocols for Water and Wastewater Utility Assets* (Marlow et al. 2007). ▪ WERF research starting up 2007 (WERF 2006) ▪ Computer Aided Rehabilitation of Sewer Networks (CARE-S) and water systems (CARE-W) underway by European 5th Framework (listed in Kirby 2005). ▪ Recent UKWIR project on Deterioration Rates of Sewers (listed in Kirby 2005). ▪ UKWIR project on condition grading of water mains (UKWIR In Progress (b)) ▪ WERF-funded research in this area for sewer pipes (Ramani 2006) ▪ USEPA Office of Research & Development is considering funding research on condition assessment, as well as rehabilitation of water infrastructure. ▪ Many other research projects recently performed or underway.
Matching non-destructive evaluation techniques to pipe types	(Continued)

Table 6.1 (continued)

Identified Needs	Current/Ongoing Activity Addressing Similar Needs
Prediction of Pipe Failure	
Improve understanding of pipe failure and deterioration processes. Breakdown by pipe, joint, lining and coatings. Recognition of differences between gravity sewers; and pressurized water or wastewater pipes	▪ AwwaRF long term performance research on pipe materials and components such as ductile iron pipe (National Research Council Canada In Progress (b)), PCCP (Boyle Engineering Corp. In Progress), PE pipe (Davis et al. 2007), PVC pipe (Burn et al. 2005), and elastomeric components (Rockaway 2007). ▪ AwwaRF funded models/forecasts of pipe rehabilitation; an early version of KANEW (Deb et al. 1998), T-WARP for large diameter water mains (Kleiner et al. 2005), and D-WARP which consider dynamic and static influences on individual water mains (National Research Council Canada In Progress (a)). ▪ Computer Aided Rehabilitation of Water Systems (CARE-W) and Sewer Networks (CARE-S) underway by European 5th Framework (listed in Kirby 2005). ▪ Research applying CARE-W in N. America, like the Las Vegas case study (Vanrenterghem-Raven et al. 2007)
A national database of failures, causes and renewal methods, including standard reporting methods. Standardization of asset data to enable research on failure trends using large data sets. Central depository of high quality data available to researchers.	▪ WERF research starting up 2007 (WERF 2006) ▪ UK national database of main breaks, maintained by UKWIR (Hale et al. 2006).
Improved methods of identifying leaks using acoustic and other methods to reduce consequence of failure	▪ AwwaRF studies: leakage management for the distribution system (Fanner et al. 2007) or service lines (Le Gouellec and Cromwell 2007), development of a new leak detector (Gas Technology Institute In Progress (a)), and using continuous system acoustic leak monitoring (American Water In Progress).
Prediction of Non-Pipe Asset Failure	
Deterioration modeling for water reservoirs and non-infrastructure concrete structures (UKWIR 2002)	
Assessment of Technologies Applicable to Asset Management Overall	
Review of existing technologies and opportunities for new technologies	▪ As an outcome of GWRC discussions, USEPA is investigating further actions following from a 2006 workshop it sponsored on Innovation and Research for Water Infrastructure (Ramani 2006).
Asset renewal technologies, especially for buried piping.	▪ AwwaRF studies on innovative water main renewal techniques (Deb et. al 1999); lead pipe repair and rehabilitation (Kirmeyer et al. 2000); rehabilitation of wells (Lennox et al. 2006) and in situ epoxy lining (Conroy et al. 1995).

7.0 CONCLUSION

This White Paper was compiled to serve as a resource to participants in an upcoming workshop on asset management research priorities. The White Paper documents various components of the "asset management paradigm" and compares actual practices with idealized practices. The White Paper then identifies a range of candidate topics for further research, based on the literature and other recent workshops.

As this paper demonstrates, the asset management paradigm is very broad. It covers every aspect of managing physical assets, as well as the organizational structures, risk-management approaches and financial management practices of water and wastewater utilities. However, while there are some exceptions, comprehensive application of the paradigm remains rare in North America at this time.

Besides AwwaRF, numerous organizations in the water and wastewater field and other industries are actively sponsoring initiatives involving asset management. Collectively these initiatives address, at least in part, each of the three categories of needs presented in this paper:

1. Education and training to disseminate knowledge and skills in asset management to more utilities;
2. Tools for data management, risk assessment, decision-making and financial management;
3. Understanding in physical science and development of new or improved technologies for specific types of assets.

Since these various efforts are unfolding at this time, it is difficult to evaluate how they will meet the needs identified in Section 6. This is particularly true of initiatives in Category 1 (education/training) and Category 2 (efforts to improve and disseminate practical tools). Their actual contribution to asset management development will not be known for some time to come.

In this environment, the challenge for AwwaRF is how to deploy resources to complement these ongoing efforts and meet needs that would otherwise not be met. This requires consideration not only of needs in the water industry, but also of AwwaRF's particular orientation and capabilities.

From a needs perspective, it appears the greatest opportunity for advancing asset management in North America is to provide education and training throughout the industry (Category 1). Education is needed to demonstrate the value of asset management to upper level utility managers and their governing boards since these are the internal leaders with the ability to launch and lead asset management initiatives. In this area, education on financial planning may offer the greatest leverage, as this area can prompt action in all the other areas of asset management. Education and training are also needed to provide staff at all levels of utility organizations with the skills and knowledge needed to make asset management practical and demonstrate concrete benefits.

While the need in Category 1 is great, this is not the best area for direct AwwaRF activity. This is because other types of organizations such as AWWA, EPA, universities and technical institutes are more suitable for leading education and training initiatives. In addition, WERF is currently funding a Web-based system to provide information on asset management to practitioners, with funding contributed by AwwaRF to include the potable water industry.

Therefore, AwwaRF's strategy in regard to Category 1 should be to maintain links with organizations developing education and training programs, complementing the normal route

AwwaRF uses to disseminate results of its research. These links with other organizations can be instrumental in ensuring training materials expressly consider water industry issues. In addition, contact with organizations sponsoring education and training programs offers a channel through which non-proprietary information developed by AwwaRF can be disseminated to many users. This can complement AwwaRF's traditional channels for distributing research results.

AwwaRF is better suited to make direct contributions in Category 2. Improvement of available tools and techniques (Category 2) will enable utilities that have embarked on the asset management journey to make their programs successful while avoiding inefficiencies in areas of common need. Areas of greatest need appear to be practical methodologies for risk assessment/risk management, life-cycle cost analysis, and cost-benefit analysis. Development of a standard framework for information and data management in water utilities could also offer significant benefits. For each of these topics, there is a need to improve tools targeting the specific issues or the water industry. Information from other industries is available and adaptation of these approaches for the water industry is one area where gains could be made rapidly.

Similarly, AwwaRF is well-equipped to sponsor research in Category 3. Advances in science and technology are needed so that financial resources available for buried pipe renewal are spent as effectively as possible. The greatest needs in this area appear to be improved abilities to assess the condition and performance of buried pipes and to predict their rate of performance deterioration. Technologies for extending the lifetime of assets also have high value. These kinds of technical advances probably offer the greatest benefits to utilities that already employ the programmatic tools of asset management covered by other forms of research. However, even without a formal asset management program, utilities can benefit from technologies that identify failing assets or provide cost-effective means to postpone deterioration and improved methods to renew assets. In this sense, scientific knowledge and technology complement and extend asset management programs, but improvements in these areas are also independent of asset management as a practice.

The benefits of Categories 1, 2 and 3 can also be differentiated in terms of timing. At this juncture, the North American water and wastewater industries may be more in need of new activity in Categories 1 and 2, rather than in Category 3. This is because, as long as the basic practices of asset management are not yet being used, advanced science and technology cannot be used to the greatest advantage. However, science and technology take time to develop. It is important to recognize needs that must be met five to ten years in the future and provide sufficient lead time to develop solutions. Therefore, while Categories 1 and 2 appear to be the greatest immediate priority, there is also a high value now in funding Category 3 activities.

These different categories also affect how the value of asset management research can be used in the water industry and wastewater industry, respectively. Generally the programmatic types of advances supported by Category 1 activities (education and training) and Category 2 activities (improved management tools) have broad application to both the water and wastewater industries. This is because the utility organizations needing these inputs are similar in structure and character.

In Category 3 (Physical Science and Technology) there is also considerable overlap in benefits of research to the water and wastewater industries, respectively. Both industries have extensive buried assets and need the capability to assess these assets and predict failure rates. However, this is where some significant differences also appear. For example, there are significant differences in failure modes for pressurized potable water pipes, compared with gravity sewer lines. Differences in the type of materials used and condition assessment techniques also lead to differing research needs between these two industries.

At the present time there are many opportunities for AwwaRF to collaborate with other organizations on asset management initiatives, both within North America and overseas. It is suggested AwwaRF remain actively engaged with partner organizations for purposes of coordination and to promote dissemination of effective practices and newly emerging knowledge. At the same time AwwaRF should carry out additional work on topics that are both critical and unique to potable water utilities.

This White Paper has assembled and organized information as a first step in developing AwwaRF's Asset Management Research Needs Roadmap. The categories and topics presented above were discussed further at the project workshop, held after this paper was prepared. Workshop participants were asked to apply their knowledge and experience to recommend priorities for AwwaRF activity to further advance the practice of asset management in North America.

Priorities identified at the workshop and through follow-up activity on this project will be recommended to AwwaRF for consideration of funding beginning with the 2008 research funding cycle.

APPENDIX A-1
AWWARF ASSET MANAGEMENT RESEARCH – PLANNING, POLICY AND MANAGEMENT TOOLS

AwwaRF Asset Management Research – Planning, Policy and Management (Updated December 2007)

Planning, Policy and Management					
Proj #	**Rep #**	**Project Topics and Titles**	**Yr Published**	**Objective (from AwwaRF website's Project Profile or Project Snapshot)**	**Research Partner**
462	90821	Financial and Economic Optimization of Water Main Replacement Programs	2001	The objective of this research was to identify and document "best practices" in planning for rehabilitation and replacement of aging, deteriorated water main piping at a broader level of optimization than undertaken previously. Unlike past work, this research focused on identifying truly comprehensive planning and management processes.	
2921	90843	Water Treatment Plant Infrastructure Assessment Manager	2001	The objective of the project was to assist users in organizing, conducting, and recording the results of a water treatment plant (WTP) assessment. The result is the creation of The Manager, a personal computer software program that evaluates the physical condition of the WTP's systems to identify those portions most in need of improvements. This aids in developing a prioritized list of improvements for planning and capital budgeting. The Manager provides an organized method that will reduce the time needed to assess the condition of a facility.	
2607	90918	Costs of Infrastructure Failure	2002	The objective of this project was to establish a comprehensive framework for evaluating costs of infrastructure failure. The framework was to encompass both tangible (direct costs to utilities) and intangible costs (“social costs” to society as a whole). Within this framework, the project was to produce two outputs: (1) a review of available approaches to estimating costs in each category and (2) a what-if spreadsheet tool to support comprehensive cost analysis.	
2633	90970	Selection and Definition of Performance Indicators for Water and Wastewater Utilities	2003	The objective of this project was to select and define between 5 and 20 high-level performance indicators for water and wastewater utilities, recognizing that others could be added. The QualServe business systems were chosen as an organizing framework to guide the design effort so the initial performance indicators database would be familiar to the many utilities participating in other elements of that program.	AWWA
2870	91081	Customer Acceptance of Water Main Structural Reliability	2005	The objective of this project was to develop an approach for utilities to assess customer perceptions, attitudes, and expectations for water main reliability; evaluate their tolerance to service disruptions and construction impacts; estimate their willingness to pay (WTP) for expected levels of service; and develop strategies to communicate with customers.	US EPA

2848	91095	Asset Management Planning and Reporting Options for Water Utilities	2006	Managers of drinking water utilities face the difficult task of identifying appropriate levels of renewal and replacement spending, and achieving buy-in for the required funding levels from boards and councils. This project was commissioned to provide the framework to identify and test several levels of asset management planning, using samples of assets from a dozen participating utilities.	
2947	91096	Benchmarking Water Utility Customer Relations Best Practices	2006	This project sought to (1) identify customer relations best practices from other relevant organizations, (2) identify metrics for both internal performance tracking and external comparison, and (3) develop tools that will enable water utilities to improve customer relations, with the ultimate goal of improving customer satisfaction and utility efficiency.	
2953	91138	Applicability of Reliability-Centered Maintenance in the Water Industry	2006	The objectives of this project were to (1) assess how water utilities can apply reliability-centered maintenance (RCM) to new and existing infrastructure and to (2) evaluate costs and benefits of RCM programs at water utilities.	
2811	91163	Evaluating Water Loss and Planning Loss Reduction Strategies	2007	This project sought to evaluate the definition, measurement, and reporting methods for water loss in public water supplies, and to provide guidance on planning for effective water loss reduction.	
2939	91168	Risk Analysis Strategies for Credible and Defensible Utility Decisions	2007	The principal objectives of the research were to (1) complete a baseline assessment summarizing current risk management frameworks, techniques, case studies, best practice examples, and decision-making capability among selected utilities; (2) gather alternative approaches to managing risk; and (3) conduct and analyze case studies.	
2935	91149	Water Efficiency Programs for Integrated Water Management	2007	The objectives of this project were to (1) develop a rigorous and universally-applicable set of definitions of benefit and cost components from different perspectives, (2) compile, in an easily-accessible form, the best available information on water use efficiency (WUE) program costs and savings, and (3) provide clear guidance to water utilities on program cost and benefit estimation.	CUWCC, US EPA
2928	91180	Leakage Management Technologies	2007	The primary objectives of this project were to (1) review proactive leakage management technologies used internationally, with a focus on the United Kingdom, (2) assess the applicability of these technologies to North American water utilities and select the most suitable technologies for pilot installations in participating utilities, and (3) provide guidance on how to practically and cost-effectively apply these technologies to North American water utilities based on the research and hands-on installation of promising techniques in controlled pilot areas.	Dallas Water, Birmingham Water Works Board, US EPA
3048	3048	Condition Assessment Strategies and Protocols for Water and Wastewater Utility Assets	2007	Document the broad range of available asset assessment tools and techniques, and provide guidance on how to incorporate condition assessment strategies into a utility's asset management philosophy. This report also provides descriptions and reviews of 84 individual condition assessment tools and techniques used in the water and wastewater industries, including a discussion of principles, applications, practical considerations, advantages, and limitations. Obtain PDF of final report (published by WERF) from AwwaRF's website.	WERF, US EPA, and CSIRO

4002	ongoing	Asset Management Research Needs Roadmap		Will develop a well-referenced white paper on asset management. Will convene and organize an asset management experts workshop to discuss and develop a multi-year research needs roadmap on asset management related topic areas.	US EPA
4013	ongoing	Sustainable Infrastructure Management Program Learning Environment (SIMPLE), Version 1.1		Will develop an effective asset management planning and learning tool for drinking water utilities. Will modify the existing wastewater-specific asset management website SIMPLE launched by WERF, to create a drinking water/wastewater tool called SIMPLE, version 1.1.	WERF
4111	ongoing	Case Studies of Best Practice and Innovation in Asset Management		Each collaborative partner will develop short case studies of water utilities that exhibit best practices or innovation in asset management. AwwaRF will develop five case studies of drinking water utilities in N. America. Water Research Commission (S. Africa) will compile the water and wastewater case studies from the collaborative partners (representing five countries) into a Compendium of Best Practice and Innovation in Asset Management. The GWRC will allow the participating organizations to publish the final report.	GWRC: WERF, UKWIR, WRc and WSAA
4108	ongoing	Data Requirements for Condition Assessment of Buried Water Infrastructure		Will define data elements required for condition assessment of buried assets for a number of expected management approaches. Will create and test a standardized framework for data structure.	GWRC (WERF)
4127	ongoing	Methodology for Cost and Benefit Valuation in Asset Management Decision Support		Will develop an electronic-based methodology to balance maximal service performance of assets with minimal cost of ownership. Will evaluate benefits, compare direct and indirect costs, determine present value, allow for triple bottom line accounting, and value risks for failure. WERF has contracted this project to GHD.	GWRC (WERF and UKWIR)
4126	ongoing	Tool for Risk Management of Water Utility Assets		Will develop a framework and electronic tool to enable water and wastewater utilities to adopt a common understanding and common principles in risk management of their assets, conforming with relevant international standards and best practices and allowing risks to be compared and prioritized between utilities and other organizations. Will devise an approach, adaptable to individual circumstances, for utilities to assess and manage the risk of their assets, covering cost, decision models, strategic security, the role of expert judgment, and the impact of asset standards on performance (including environmental), customer service, and investment requirements. The report will include a CD with the electronic tool. The electronic tool will be integrated into the SIMPLE website. UKWIR has contracted this project to Mott MacDonald.	GWRC (UKWIR, WERF and WSAA)

4085	ongoing	Setting Water Utility Investment Priorities: Assessing Customer Preferences and Willingness to Pay		Will develop more robust tools to better characterize customer input to utility investment priorities. Will review survey approaches for eliciting accurate customer preferences, will describe how such tools have been used in public decision-making, and will test the tools in water utility customer surveys. Also will develop a handbook that provides guidance to utilities and their vendors on designing, implementing, and analyzing customized "willingness to invest" surveys for typical utility investments.	

APPENDIX B-1
AWWARF ASSET MANAGEMENT RESEARCH – CONDITION ASSESSMENT

Condition Assessment					
Proj #	**Rep #**	**Project Topics and Titles**	**Yr Published**	**Objective (from AwwaRF website's Project Profile or Project Snapshot)**	**Research Partner**
725	90508, 2nd Ed.	Internal Corrosion of Water Distribution Systems, Second Edition. A Cooperative Research Report	1996	Reports on internal corrosion of potable water system piping material, covering principles of corrosion, corrosion of specific materials, mitigation, assessment, and corrosion control strategies. Second edition published in 1996.	DVGW-Technologiezentrum Wasser, Karlsruhe, Germany
393	90770	Leak Detection Methods for Plastic Water Distribution Pipes	1999	The main objective of this research project was to investigate the effectiveness of commonly used acoustic leak detection equipment, in particular leak noise correlators, for locating leaks in plastic water distribution pipes. Emphasis was placed on evaluating the methods on which the equipment is based-not on comparing different makes of equipment. Objectives of the research also included performing a world-wide survey of leak-detection equipment, characterizing leak sounds in plastic pipes, identifying necessary improvements to existing equipment and procedures and evaluating the potential of alternative nonacoustic technologies from other industries.	
2564	90854	Electromagnetic Inspection of Prestressed Concrete Pressure Pipe	2001	The focus of this project was the theoretical advancement and practical appslications of the Remote Field Eddy Current/Transformer Coupling (RFEC/TC) inspection technique. This unique, non-destructive technology can be used to provide a reliable condition assessment of prestressed concrete cylinder pipe (PCCP). An improved understanding of this emerging technology may increase the range over which the technology may be applied for the benefit of the drinking water community. With aging water pipeline infrastructure, a nondestructive testing method to evaluate the integrity of the PCCP is essential. Detection of broken prestressing windings is crucial in assessing pipe condition so that informed pipeline management decisions can be made.	
355	90873	Nondestructive, Noninvasive Assessment of Underground Pipelines	2002	This project was directed toward developing and collecting data to support the selection of nondestructive evaluation (NDE) methods for inspection of waterworks piping systems. NDE methods and technologies were analyzed for application to waterworks inspection, and full-scale demonstrations of those technologies were then conducted to assess their use in the metropolitan utility environment.	

2612	90961	Techniques for Monitoring Structural Behavior of Pipeline Systems	2004	The major objective of this project was to investigate techniques to monitor the structural integrity of water supply systems. The primary interest was in mains of 30-in. diameter and larger, and those that are classed as operationally critical. Critical parameters for continuous monitoring had to be identified for the range of pipe materials most commonly used for water distribution, and potential monitoring technologies had to be identified, which could be used to monitor these parameters.	
2681	91032	Assessment and Development of Low-Pressure Membrane Integrity Monitoring Tools	2004	The overall objective of the research was to assess and advance membrane integrity monitoring methods for MF/UF processes. To achieve this objective, current state-of-the-art existing methods were assessed and then recommendations were made for selection and improvement of existing methods.	UK DWI
2871	91028 F	Workshop on Condition Assessment Inspection Devices for Water Transmission Mains	2004	The aim of the project was to conduct a state-of-the-art literature review of noninterruptive condition assessment inspection devices for large diameter transmission mains (greater than 12 inches). In addition, an expert panel workshop was to be held to review business needs and drivers, the performance of existing technologies, and future underground asset condition assessment research needs.	
2608	90987	External Corrosion and Corrosion Control of Buried Water Mains	2005	The objectives of this project were to 1. develop methodologies, techniques, protocols, and technology for identifying the specific conditions that lead to corrosion failures in the water utility, 2. identify economical solutions appropriate for the waterworks industry for each type of external pipeline corrosion, 3. verify promising techniques for the most prevalent problems through field trials, and 4. develop a Corrosion Control Master Plan and a systematic risk-based approach to corrosion control to foster a better understanding of the benefits and value of corrosion control in the water utility industry.	
2727	91053 F	The Effect of Corrosion Pitting on Circumferential Failures in Grey Cast Iron Pipes	2005	The primary goal of the study was to determine typical sizes of corrosion pits that contribute to circumferential failure. This information would be expected to be of use in designing non-destructive testing tools for use in water mains. Secondary goals included determining contributing environmental conditions around the pipe and examining the causes of particular types of pipe failure.	NRC, Ca
2689	91126	Potential Techniques for the Assessment of Joints in Water Distribution Pipelines	2006	The project sought to identify and document the key problems associated with the failure of joints in water distribution pipelines and to investigate and report on the potential of existing and emerging techniques for the location, condition assessment, and repair of these joints.	
2936	91151	Minimizing Operational Interruption During Filter Bed Surveillance	2006	The overall objective of this project was to identify, review, and select potential filter evaluation methods that are less interruptive than conventional techniques. These condition assessment methods provide information on the overall process performance of a filter and the condition of the granular media.	US EPA

2927	91167	Installation, Condition Assessment, and Reliability of Service Lines, Connections and Fittings	2007	Background leaks from buried service lines can account for a large portion of real water losses, not only because they are “out of sight, out of mind,” but also because ownership issues exacerbate the problem. The research addressed the following four areas: Service line materials, Installation techniques (installation, protection, and recommendations), Condition assessment (failure determination, failure causes, and service line management), and Guidelines to utilities (recommendations and a service line information tool).	
3129	ongoin g	Smart Sensors for Buried Utility Location and Performance Monitoring		Will explore the feasibility of introducing “smart infrastructure monitoring systems” into pipeline practice by addressing the practical issues associated with implementation. Will examine the use of smart pipe not only to determine the location of buried pipe but also the condition of the pipe.	UKWIR and University of Birmingham

APPENDIX C-1
AWWARF ASSET MANAGEMENT RESEARCH – LONG TERM PERFORMANCE PREDICTION

AwwaRF Asset Management Resaerch – Long-term Performance Prediction (Updated December 2007)

Long-term Performance Prediction					
Proj #	**Rep #**	**Project Topics and Titles**	**Yr Published**	**Objective (from AwwaRF website's Project Profile or Project Snapshot)**	**Research Partner**
280	90787	Investigation of Grey Cast Iron Water Mains to Develop a Methodology for Estimating Service Life	1996	The principal objective of this research project was to develop a methodology that would assist water distribution engineers in estimating the optimum time to replace water mains. The methodology would integrate information on corrosion-induced pit dimensions, effective pipe-wall thickness, residual strength of grey cast iron, corrosion rates, and the mechanical behavior of metallic water mains. Secondary objectives were to determine the most effective and practical approaches to measure the residual strength of grey cast iron pipe, to determine whether current or near-term nondestructive testing technology could be used to produce the necessary information on corrosion pit dimensions and to expand the current state of knowledge with respect to the mechanical behavior of grey cast iron water mains.	
2879	91092 F	Long-Term Performance Prediction for PVC Pipes	2005	The objectives of this study were to (1) outline water quality issues in PVC pipes; (2) compare performance standards in the United States/Canada and Australia; (3) quantify field performance of PVC pipes; (4) determine fracture properties of U.S./Canadian and Australian PVC pipes; (5) develop and benchmark a long-term performance prediction model for PVC pipes under a range of installation and operating conditions; and (6) benchmark this model against historical failure data held by water utilities.	CSIRO
2941	91154	Service Life Analysis of Water Main Epoxy Lining	2006	The objectives of this research were to (1) gather information on historical epoxy lining installations and document the effectiveness of these previously installed liners in protecting cast iron or steel water mains; (2) develop protocols and procedures and conduct accelerated life-cycle tests on epoxy liners to assess their long-term performance; and (3) assess the longevity of early epoxy liner installations for renewal planning.	
2932	91197	Performance of Elastomeric Components in Contact with Potable Water	2007	This research initiative was intended to clarify the factors that contribute to elastomer degradation and provide a quantitative method for predicting the performance and life expectancy of in-service elastomer components. Specifically, the primary objectives of this project were to (1) establish a quantitative method for predicting the life expectancy of in-service elastomer components when exposed to potable water, (2) identify elastomeric materials with high performance when subjected to chloramines, and (3) provide the water industry better tools for managing the risks and financial costs associated with elastomer failure.	US EPA

2975	91194	Long-Term Performance Prediction for PE Pipes	2007	The objectives of this study were to (1) review the current field performance for polyethylene (PE) water pipelines; (2) review U.S. and international standards for PE water pipes; (3) review previous and state-of-the-art test methods and modeling techniques for service lifetime prediction of PE pipelines; (4) identify and measure relevant pipe properties that govern long-term field performance; and (5) develop and benchmark models to predict long-term field performance of PE pipes	CSIRO
3112	91174	Performance and Metal Release of Non-Leaded Brass Meters, Components, and Fittings	2007	The primary objectives of this project were to synthesize the current state of knowledge related to the use of non-leaded brass components in drinking water, identify and prioritize recommended research needs related to non-leaded brass, and provide a preliminary structure for the top priority projects to meet those needs.	US EPA
2946	91204	Impact of Hydrocarbons on PE/PVC Pipes and Pipe Gaskets	2008	The objective of this project was to study the impact of hydrocarbons on polyethylene (PE) and polyvinyl chloride (PVC) pipes and elastomeric gaskets. Specific tasks were to (1) survey water utilities to learn about their experiences with plastic pipes and permeation of mains and services, (2) study permeation through PE and PVC pipes exposed to hydrocarbon contamination, (3) develop laboratory tests to predict permeation of pipes and gaskets, and (4) study permeation through pipe gaskets exposed to hydrocarbons.	
3036	ongoin g	Long-Term Performance of Ductile-Iron Pipe		Will evaluate and recommend testing and evaluation methods for buried DI pipes, and will develop improved accelerated material life testing methods for DI pipe. Will integrate these methods to better predict the long-term performance and life expectancy of DI pipes.	NRC, Ca and CSIRO
3126	ongoin g	Life Expectancy of Field and Factory Applied Cement-Mortar Linings in Ductile-Iron and Cast-Iron Water Mains		Will predict the time to failure and determine the mechanisms of failure of both field- and factory- applied cement-mortar lining (CML). Will develop a procedure/protocol to predict remaining life and identify modes of failure of CML in ductile-iron and cast-iron water mains.	CSIRO
4093	ongoin g project	Long-Term Performance of Asbestos Cement Pipe		Will present a comprehensive document for strategic management of remaining AC pipe in service in North America. Will identify the performance of AC pipe, methods to assess expected remaining life expectancy, and practical approaches for repair, replacement, and disposal of AC pipe given worker safety and environmental requirements.	NRC, Ca

APPENDIX D-1
AWWARF ASSET MANAGEMENT RESEARCH – REPAIR, REHABILITATION AND RENEWAL

AwwaRF Asset Management Research – Repair, Rehabilitation and Renewal (Updated December 2007)

Repair, Rehabilitation, and Renewal					
Proj #	**Rep #**	**Project Topics and Titles**	**Yr Published**	**Objective (from AwwaRF website's Project Profile or Project Snapshot)**	**Research Partner**
265	265	Quantifying Future Rehabilitation and Replacement Needs of Water Mains	1998	The objectives of this project were to develop a user-friendly software suitable for use by North American water utilities for forecasting water main rehabilitation and replacement needs, demonstrate the effectiveness and applicability of the developed software by testing it at different water utilities, develop a user guide for the software and identify the characteristics of North American water distribution systems in terms of rehabilitation and replacement needs. In this project, a user-friendly software (KANEW) was developed for North American utilities based on a model (KAMODEL) previously developed in Germany.	
255	90768	Demonstration of Innovative Water Main Renewal Techniques	1999	The objectives of this project were todemonstrate and evaluate various trenchless technologies as alternatives to open-trench rehabilitation and replacement of water mains, and identify conditions under which each technology can best be applied under North American conditions and document these applications by video showing the methodologies and problems associated with each application.	
465	90789	Lead Pipe Rehabilitation and Replacement Techniques	2000	The objective of the project was to test and evaluate existing technologies and promising emerging technologies for the rehabilitation or replacement of lead pipe in the distribution system.	
2629	90846	Distribution Infrastructure Management: Answers to Common Questions	2001	This report looks at previous AwwaRF projects and other information and provides general guidelines to utility managers and engineers regarding the development and execution of an infrastructure management program.	
459	90898	Prioritizing Water Main Replacement and Rehabilitation	2002	The main goal of the project was to describe procedures and tools that a utility could use in developing practical and cost-effective distribution system renewal (i.e. rehabilitation and/or replacement) programs by taking advantage of the data collected during water main breaks. A primary focus of the project was to make sure that the data requirements were practical and within reach of most utilities.	
2519	90892	Decision Support System for Distribution System Piping Renewal	2002	The objectives of this study were to provide guidance to water utilities in considering the important criteria for selecting suitable technologies and pipe materials and develop a comprehensive decision support system that facilitates the selection of the most appropriate renewal technology for distribution system infrastructure based on present worth costs and environmental considerations.	

2688	90938	Investigation of Pipe Cleaning Methods	2003	The objective of this project was to provide guidance to utility managers and engineers for managing pipeline cleaning programs. Guidelines included criteria for selecting pipes to be cleaned. decision support tools for selecting cleaning methods, data needed for informed decisions and effective program management, analytical methods for determining cleaning frequencies and techniques for measuring results.	
2772	91025 F	Assessment and Renewal of Water Distribution Systems	2004	The objectives of this project were to synthesize the knowledge base on condition assessment, repair and rehabilitation, and prioritization; to expand the knowledge base to lead to optimal capital management strategies for utilities; to help plan a responsive research agenda for the water supply industry; to help utilities use results of research projects; and to provide a critical evaluation and an assessment of requirements for implementing tools.	
2883	91087	Risk Management of Large-Diameter Water Transmission Mains	2005	The first objective of the project was to develop a method to interpret distress indicators, observed during inspection and/or non-destructive evaluation (NDE) session, to obtain a condition rating of water transmission mains. This method should consider both scarce field data and expert opinion. The research team also planned to develop a method to model the deterioration process of large-diameter water transmission mains, and the associated increase in failure risk. Lastly, the team planned to develop a method to examine, compare, and select effective renewal strategies.	NRC, Ca
461	91165	Main Break Prediction, Prevention, and Control	2007	The original project objective focused on cause and consequence factors for risk from main breaks and leaks, a methodology to assign risk factors to individual pipes, and specific information about risk variables. The project was not finished on its original schedule, but useful research was accomplished. Part of the project effort was devoted to preparing the software for main renewal planning, but the software was not finished and is not included in this report. This report includes a literature review about main break prediction, results of a utility survey, a summary of work accomplished on the project's modeling objectives, and updated information about predicting main breaks	
2869	91136	Criteria for Valve Location and System Reliability	2007	The objectives of this research were to develop a rationale for valve location using design rules to optimize system reliability, to develop an easy to use program to analyze the efficiency of valves on the reliability of isolation of distribution networks, and to develop a computer model to analyze complicated networks and assist water utilities in minimizing interruption of supply in isolating water main breaks.	
2872	91156	No-Dig and Low-Dig Service Connections Following Water Main Rehabilitation	2007	The objective of this study was to develop, analyze, and test various concepts for reconnecting service laterals after pipeline rehabilitation with little or no excavation. By discussing and demonstrating various concepts, it was hoped that the technical challenges would be better understood, and practical new tools and techniques would ultimately emerge to significantly reduce the cost of rehabilitating water mains. The study focused on pipelines and conditions common to water distribution systems.	

2956	91177	Guidelines to Minimizing Downtime during Pipe Lining Operations	2007	Repair and maintenance of existing distribution lines is an increasing concern for utilities. While pipe lining activities are effective and generally less expensive than complete replacement, they still represent considerable time and expense. The purpose of this research was to provide guidance on the best practices to minimize the downtime associated with pipe lining operations. In this context, “downtime” refers to the amount of time customers are without water service, must endure restricted service, or are served by less secure networks.	
3065	3065	Performance and Cost Targets for Water Pipeline Inspection Technologies	2008	This project attempted to establish generally accepted cost and performance criteria for the next generation of water pipeline inspection technologies, building on the results of the recently completed AwwaRF project, Workshop on Condition Assessment Inspection Devices for Water Transmissions Mains (project #2871, order # 91028F). Report is as PDF on AwwaRF website.	US EPA
3090	91210	Autogenous Healing of Concrete in the Drinking Water Industry	2008	The objective of this project was to examine the effects of bulk water chemistry on concrete corrosion and autogenous repair of concrete.	
2967	ongoin g	Technology for Horizontal Directional Drilling		Will design, fabricate, and test a prototype sensor system for detecting metallic, plastic, or ceramic obstacles in front of or around the head of a horizontal directional drilling rig. Will also demonstrate obstacle detection under field conditions.	GTI
3052	ongoin g	Dynamic Influences on the Deterioration Rates of Individual Water Mains		Will develop a deterioration model of individual water mains that explicitly considers both static and dynamic influences. Will provide an analytical tool to enable effective prioritization of the renewal of individual water mains.	NRC, Ca

APPENDIX E-1
AWWARF ASSET MANAGEMENT RESEARCH – LOCATION

AwwaRF Asset Management Research – Location (Updated December 2007)

Location					
Proj #	Rep #	Project Topics and Titles	Yr Published	Objective (from AwwaRF website's Project Profile or Project Snapshot)	Research Partner
2524	90859	New Techniques for Precisely Locating Buried Infrastructure	2001	The objectives of this study were to 1-identify mature, developing, and emerging technologies for accurately locating metallic and nonmetallic buried assets in a wide range of environments, 2-evaluate and compare the accuracy of various technologies, 3-provide recommendations to produce specifications and guidance for improving existing or developing new technologies, and 4-recommend the most appropriate technologies to utility companies with respect to accuracy, data quality, time, and ease of use.	
2882	2882	Multi-Utility Buried Pipes and Appurtenances Location Workshop	2002	A workshop was held in London in May 2002 with the purpose of bringing together a group of experts from the UK , US, and the Netherlands to1-focus on buried pipe and appurtenance location technologies, 2-review state of the art technologies. 3-develop cost and performance specifications for tools for locating buried pipes and appurtenances. 4-address the limitations of current technologies and 5-identify future technology development and research needs. Published by UKWIR. Summary available upon request.	UKWIR
3050	ongoing	Development of an Advanced Tracer Wire Terminator/Coupler		Will prototype and test components of a permanently buried termination device for trace wire that facilitates signal injection, corrosion protection, and positive identification of pipes buried below the trace wire. Will also perform accelerated life tests on the prototypes. Will monitor utility field tests of the prototypes to determine their performance including tracer signal coupling under a wide range of soil conditions and ability to reliably return an ID signal.	GTI
4041	ongoing	Development of a Digital Leak Detector		Will develop and eventually commercialize a product capable of precisely locating pinhole leaks in distribution systems (water, natural gas, and steam). If successful will result in less costly repair due to both early warning and more precise location of leaks and therefore smaller, less expensive and invasive excavation. GTI will publish a report that AwwaRF will make available only to its subscribers.	GTI
3133	ongoing	Underground Facility Pinpointing—Finding a Precise Locating System for Buried Underground Facilities, Phase II		Will evaluate the use of several emerging technologies in locating and pinpointing buried water mains. Will include pipe materials, pipe diameters, burial depths, soil environments and other issues directly relevant to water distribution networks, and field studies to evaluate recent advancements made in ground-penetrating radar.	GTI

APPENDIX B

WORKSHOP SUMMARY

APPENDIX B
WORKSHOP SUMMARY

This Appendix contains a summary of the workshop-related materials including a letter of invitation, workshop agenda, a list of attendees, potential projects, rankings, and conceptual project descriptions.

November 2, 2006

Subject: AwwaRF Asset Management Workshop

Dear Workshop Participants

We wanted to provide you with some of the particulars related to our upcoming Workshop on the Asset Management Research Needs Roadmap.

It will be held at the American Water Delran Water Treatment Plant and Conference Center in New Jersey, which is about a 30 minute ride from the Philadelphia Airport.

Participants will generally arrive on Sunday December 3, and will attend the workshop for a full day on Monday, December 4, and one half day on Tuesday, December 5, 2006. The Tentative Schedule may be found in Enclosure 1 – Workshop Schedule of Events.

We have a block of rooms being held at the Marriott Hotel at 915 Route 73 in Mount Laurel, New Jersey. You are responsible for making your own hotel reservations as well as any cancellations. To reserve a room we ask that you please contact Marriott Reservations toll free at 1-888-236-2427 (or from outside the US please call the hotel directly at 856-234-7300 and they will transfer you to a reservation representative) and use either code name **AWEC** or **American Water** to receive the discounted room rate of $129/night and be included in the reserved block of rooms. Please reserve your room by November 20, 2006. See Enclosure 2 for directions and more information.

We will provide transportation between the Delran Plant and the hotel on Monday and Tuesday. It will be your responsibility to get to the hotel from the airport on Sunday. On Tuesday, December 5, 2006, shuttles to the airport starting at 12:15 pm will be available at the going rate for your convenience. It is also your responsibility to pay for transportation, lodging and incidental meals outside of the Workshop venue as those are considered your in-kind services contributions to the Project.

We will have the technical White Paper for you to review about 1 to 2 weeks before the Workshop. It will be available at the Project Web site www.waterassetmanagement.com. We will notify you via email when it is available.

Questions regarding technical matters or overall project issues contact Gregg Kirmeyer, 425-450-6291 or email g.kirmeyer@hdrinc.com. Questions regarding logistics contact Julie Self at 425-468-1527 or email Julie.Self@hdrinc.com.

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Workshop Notice

AwwaRF #4002 Asset Management Research Needs Roadmap

As a participant, please review the following carefully:

What is the focus of the workshop?
AwwaRF Workshop to identify research gaps and develop asset management research roadmap for water and wastewater utilities.

Who should attend?
Much of the workshop revolves around technical and day to day aspects of asset management. As such you may consider having a staff person attend who is routinely involved in asset management.

Dates

Travel:	Sunday, December 3, 2006
Workshop:	All day Monday, December 4, 2006
	Half day Tuesday, December 5, 2006 (complete by Noon on 12/5)

Where?
American Water, Water Treatment Plant, Delran, NJ (Near Philadelphia, PA)

Limited Space
Overwhelming response and a maximum of 50 participants has resulted in the need to limit attendance to one person from each organization. If we have attrition, we may be able to expand later.

RSVP a must
To help serve you technically and logistically, please respond to Julie Self at HDR by Wednesday, October 18, 2006 via email (Julie.Self@hdrinc.com) or telephone (425.468.1527) whether or not someone from your organization is attending.

Please provide the following:

Name of Attendee: ______________________ ***Title:*** ______________________
Address: ____
____
City: ______________________ ***State:*** ____________ ***Zip:*** ____________
Telephone: ______________________ ***Fax:*** ______________________
Email: ____

Questions
Please contact Julie Self (425.468.1527) regarding logistics and Gregg Kirmeyer (425.450.6291) regarding the project or workshop particulars.

AwwaRF Asset Management Expert Workshop
December 4 - 5, 2006
Agenda Process and Preparation
(Revised 11/20/06)

Workshop Goals

- Give a summary of AM research and gaps to date
- Fully utilize the AM/W/WW utility expertise and experience of all the participants
- Get agreement on major areas of AM research needed for drinking water systems in North America primarily, and for wastewater systems where needs overlap with drinking water systems
- Get agreement on prioritization of AM research areas
- Define and prioritize specific research projects
- Develop the components of the AM Research Roadmap

Agenda and Process

Day 1 - December 4th

Item	Description	Process	Lead(s)	Time
0	Arrival	Get coffee etc. and settle in	Smith	8:00am
1	Welcome	Introductory Remarks	AwwaRF/ HDR/AW	8:30am
2	Overview of agenda, guidelines and Introductions	Introduce self and organization and specific area of AM they are most interested in (30-45 secs. each)	Smith	8:35am
3	Expert Panel	The following panel members will each have 5 minutes to highlight their AM research and results, followed by a moderated Q&A session with the participants. Panel members can bring a 2 page handout as well. No slides. AwwaRF will also have a handout but not be on the panel. • EPRI • FHA • EPA • WERF • UKWIR/GWRC • CSIRO • BAMI	Smith moderator	9:05am
	Break			10:00am

4	Presentation	Gap Analysis from white paper & Q&A Present key research areas.	Graham	10:15am
5	List major research categories	List one research category per flipchart based on results of white paper and gap analysis. Then brainstorm any further categories in the large group. This could range from 5-10 categories (In large group)	Smith	10:45am
6	Brainstorm topics within the categories	Use Open Space process to obtain input from as many participants as possible. Write one category per flipchart. Place 5 chairs around each flipchart. One team member stays with each flipchart and records ideas on research topics. The entire group gets to move around the room giving input at each station. When they are done they move on to the next group, keeping the numbers equal in each group. Purpose is to get as many ideas out from the entire group as quickly as possible without needing agreement at this stage. Participants also write their names down on flipcharts indicating their 1st and 2nd choice topics that they'd like to work on in break out groups.	Smith and team members	11:00am
	Lunch			12:00am
7	Prioritize major research categories	In large group review summaries of each research category. Then do weighted voting (10 dots each on charts) to narrow down categories (only if necessary if there are a significant # of research categories). Review results and test consensus on top 5 to 7 categories. If necessary do second weighted voting (5/3/1 dots) on those that are close in voting.	Smith	1:00pm
8	Develop ranked topics within research categories	Assign participants to break out groups, based on their preferences. Review the process for the break out groups including how to complete the project concept/ranking sheets. The criteria for ranking will be described. Team members will then facilitate the discussion of topics in the break out groups using the project concept/ranking sheets. (see example) After all project		1:45pm

8 cont		concept/ranking sheets are developed and ranked (Hi/Med/Lo), review and decide which are the top 3-5 projects to be presented the next morning to the large group. (Groups take bathroom breaks as needed)		
	Adjourn for day			5:00pm

Day 1 Evening

Facilitator will collect and summarize the project concept ranking sheets for review and comparison the next day and show the projects by ranking (Hi, Med, and Lo).

Day 2 – December 5th

Item	Description	Process	Lead(s)	Time
9	Report back from break out groups	Break out group spokesperson summarizes project concepts/ranking sheets for each category. Large group Q&A on each category.	Smith	8:00am
10	Summary of rankings	Presentation of summary of all project rankings by facilitator. Large group Q&A. Review High ranked projects to be prioritized for the ultimate Roadmap and see if any of the Medium or Low ranked projects should be included.	Smith	9:15am
	Break			10:00am
11	Re-rank the remaining topics	In large group use a weighted prioritized (10 votes) process to rank the high ranked projects. Further prioritization (5/3/1) may be done if first prioritization voting is close. Then review the top ranked projects by research area to be sure there is agreement on the balance of projects in each research area.	Smith	10:15am
12	Closing/Next Steps	Summarize results and define next steps and follow-up. Thank participants for time and effort	AwwaRF/ Smith/HDR/ AW	11:50am
	Adjourn			Noon

List of Attendees

Last Name	First Name	Company
Burton	Tod	Tualatin Valley Water District
Chelius	James	American Water
Dickerson	Dennis	City of Columbus, Dept. of Public Utilities, Water Group
Dueck	Russ	City of Calgary Water Resources
Goddard	Madeline	City of Phoenix Water Services Department
Harder	Chris	Fort Worth Water Department
Heitzman	Greg	Louisville Water Company
Kiely	Charles	District of Columbia Water and Sewer Authority
Kramer	Amy	Northern Kentucky Water District
Kummer	Jim	City of St. Louis Water Division
Lamb	Dennis	Vallecitos Water District
Marcum	Tony	City of Bellevue
Marlow	David	CSIRO Land and Water
McGhee	Terry	DuPage Water Commission
Naumick	Gary	American Water
Nielson	J. Christopher	Cleveland Water
Oberoi	Kanwal	Charleston Water System
Pai	Isaac	Long Beach Water Department
Pennington	Heather	Tacoma Water
Petrini	Arthur	Henrico County Dept of Public Utilities
Raffenberg	Mark	Greater Cincinnati Water Works
Ramani	Roy	WERF
Ries	Thomas	Aurora Water
Rurak	Dean	York Region Transportation & Works
Toth	Lisa	East Bay Municipal Utility District
Tucker	Stephan D.	Los Angeles Department of Water and Power
Vanrenterghem-Raven	Annie	Polytechnic University
Vause	Kurt	Anchorage Water and Wastewater
Whipp	Steve	United Utilities Water Services
Allbee	Stephen P.	USEPA
Basford	Chris	Newport News Waterworks
Bloom	Jeremy	Electric Power Research Institute
Connelly	David	HDR Engineering, Inc.
Cottingame	Marc	Dallas Water Utilities
DeGraca	Andrew F.	San Francisco PUC
Fortin	John	John W. Fortin Asset Management Consultant
Gaj	Stephen J	Federal Highway Administration
Graham	Andrew	HDR Engineering, Inc.
Grigg	Neil	Colorado State University
Harp	Doug	Westin Engineering
Hasit	Yakir	CH2M Hill
Haskins	Scott	Seattle Public Utilities
Hodgins	Maureen	AwwaRF
Hooker	Michael	Onandaga County Water Authority (AWWA Rep)
Hughes	David	American Water
Johnson	Joel	Advantica

Last Name	First Name	Company
Kirmeyer	Gregg	HDR Engineering, Inc.
Lovan	Ron	Northern Kentucky Water District
Petrie	Todd	City of Clearwater
Reekie	Linda	AwwaRF
Saill	Chris	Westin Engineering
Smith	Anne	Smith Culp
Templin	Bud	Westin Engineering
Tenny	Ed	HDR Engineering, Inc.
Wessels	Eric	HDR Engineering, Inc.

AwwaRF ASSET MANAGEMENT WORKSHOP
BREAK OUT GROUP – SUMMARY OF RESEARCH PROJECTS
December 4, 2006
This document contains three parts:

Projects Ranked by Workshop Participants (Highest Score to Lowest)

Rank	Score	Group #	Project #	Research Area/Research Project
1	37	6	1	Develop Best Maintenance Practice for Water Distribution Assets
2	36	5	4	IT Integration Data Model to Support AM
3	31	2	1	Risk Identification, Consequences and Mitigation Techniques Associated with Triple Bottom Line Economics.
4	28	1	1	Asset Management Implementation Strategies Guidance Document
5	26	4	2	Develop a Central Repository of Water Utility Asset Data to Support Maintenance, Repair, Rehabilitation and Replacement (MRRR)
6	20	3	5	Degradation Curves for Buried Assets
7	19	4	1	Life Expectancy of Different Asset Classes
8	18	4	3	Develop Methodologies for Prioritizing System-Wide Water Projects
9	17	1	2	Key Characteristics of Organizations with Effective AM Programs
10	15	5	2	Evaluating Strategies for Data Creation, Collection, Validation, and Maintenance for AM
11	13	3	4	Incorporate condition assessment in risk analysis

Rank	Score	Group #	Project #	Research Area/Research Project
12	11	1	3	Level of Service and Metrics Development
13	10	6	2	Identify Powerful Tools to Collect Data from Multiple Sources so that O&M Needs can be Cost Effectively Managed
14	8	3	1	Validation of Condition Assessment Inspection Equipment for PCCP
15	8	3	3	Condition Evaluation of Water Main Appurtenances
16	7	3	2	Develop Degradation Curves for Above Ground Assets
17	5	1	4	Investigate policies/strategies required to implement effective AM programs
18	5	5	3	Data Dictionary for Buried Assets
19	5	6	3	Develop Guidelines to Optimize Inventory and Materials Management
20	3	4	4	Develop Asset Classes Decision Guidelines for Maintenance, Renewal, Replacement and Run to Failure Policies
21	3	5	1	To Integrate or Not to Integrate IT in Business Practice of AM
22	2	2	2	Risk Assessment for High Consequence/Low Probability Events
23	1	2	3	Measuring and Using Customer Attitude about Risk

Projects Grouped and Project with Ranking and Score

Rank	Score	Group #	Project #	Research Area/Research Project
4	28	1	1	Asset Management Implementation Strategies Guidance Document
9	17	1	2	Key Characteristics of Organizations with Effective AM Programs
12	11	1	3	Level of Service and Metrics Development
17	5	1	4	Investigate policies/strategies required to implement effective AM programs
3	31	2	1	Risk Identification, Consequences and Mitigation Techniques Associated with Triple Bottom Line Economics.
22	2	2	2	Risk Assessment for High Consequence/Low Probability Events
23	1	2	3	Measuring and Using Customer Attitude about Risk
14	8	3	1	Validation of Condition Assessment Inspection Equipment for PCCP
16	7	3	2	Develop Degradation Curves for Above Ground Assets
15	8	3	3	Condition Evaluation of Water Main Appurtenances
11	13	3	4	Incorporate condition assessment in risk analysis
6	20	3	5	Degradation Curves for Buried Assets
7	19	4	1	Life Expectancy of Different Asset Classes
5	26	4	2	Develop a Central Repository of Water Utility Asset Data to Support Maintenance, Repair, Rehabilitation and Replacement (MRRR)
8	18	4	3	Develop Methodologies for Prioritizing System-Wide Water Projects
20	3	4	4	Develop Asset Classes Decision Guidelines for Maintenance, Renewal, Replacement and

Rank	Score	Group #	Project #	Research Area/Research Project
				Run to Failure Policies
21	3	5	1	To Integrate or Not to Integrate IT in Business Practice of AM
10	15	5	2	Evaluating Strategies for Data Creation, Collection, Validation, and Maintenance for AM
18	5	5	3	Data Dictionary for Buried Assets
2	36	5	4	IT Integration Data Model to Support AM
1	37	6	1	Develop Best Maintenance Practice for Water Distribution Assets
13	10	6	2	Identify Powerful Tools to Collect Data from Multiple Sources so that O&M Needs can be Cost Effectively Managed
19	5	6	3	Develop Guidelines to Optimize Inventory and Materials Management

Potential Projects Listed by Research Area

Group #	Project #	Research Area/Research Project	Objectives	Ranking	Score
1		**AM Frameworks/Models for Organizations**			
	1	Asset Management Implementation Strategies Guidance Document	• Investigate and compare AM Strategies across Utilities Sector. • Develop implementation strategies and guidance adaptable to water utilities of all sizes.	Hi	28
	2	Key Characteristics of Organizations with Effective AM Programs	• Identify models of organization structure that lead to sound AM practices • Define required personnel skills and organizational capabilities. • Develop implementation strategies to integrate AM into organizational practices.	Hi	17
	3	Level of Service and Metrics Development	• Determine standard level of service metrics (indicators of customer and environmental levels of service) for drinking water utilities, and relate to specific customer/stakeholder expectations. • Produce guidance and implementation strategies for utilities	Hi	11
	4	Investigate policies/strategies required to implement effective AM programs	• Identify policies required to support AM (financial models, lifecycle costing, triple bottom line). • Once policies are defined, provide guidance on how these can be translated into strategies for implementing AM programs.	Hi	5
	Notes:	• P1 and P2: determine if overlap with other AMWA NACWA guidebook • P1 and P2 could be combined			

Group #	Project #	Research Area/Research Project	Objectives	Ranking	Score
		• P1 is for organizations that are just starting out. • P4 is for organizations that already have AM • Level of service should include customer risk • Be sure metrics are consistent			
2		**Risk Management**			
	1	Risk Identification, Consequences and Mitigation Techniques Associated with Triple Bottom Line Economics.	• Identify the types of risk for the water and wastewater industry using TBC methodology. • Identify the consequences and impacts to the stakeholders (customers, regulators, Board, elected officials) • Identify mitigation techniques for the risk categories to meet stakeholder expectations.	Hi	31
	2	Risk Assessment for High Consequence/Low Probability Events	• Define what high consequence/low probability risks should be considered by Utilities. • Determine how these risks should be assessed (a common framework for analysis and tools for analysis)	Hi	2
	3	Measuring and Using Customer Attitude about Risk	• Develop and quantify a set of customer risks metrics. Engage stakeholders (e.g., Utility Management, regulators) in the development of these metrics. • Develop a tool that a water utility can use to trade-off risks vs. mitigation costs.	Hi	1
	Notes:	• Look at probability in risk calculation • P1 and 2 could be combined and/or			

Group #	Project #	Research Area/Research Project	Objectives	Ranking	Score
		phased • COE has risk metrics defined • P3: Level of risk should include customer willingness to pay. • AwwaRF currently has two projects (Linda R.): 1) Risk analysis techniques, 2) How to integrate risk in organizational culture.			
3		**Condition Assessment and Performance Monitoring**			
	1	Validation of Condition Assessment Inspection Equipment for PCCP	• Provide utilities with a user friendly list of proven, cost-effective, inspection equipment/technology for PCCP. • Provide uses, limitations, and capabilities of inspection technology.	Hi	8
	2	Develop Degradation Curves for Above Ground Assets	• Develop a formula which incorporates environment conditions to determine remaining expected life for the asset	Hi	7
	3	Condition Evaluation of Water Main Appurtenances	• Define and develop performance criteria for water main appurtenances, hydrants, valves, PRVs, service lines, air release valves and blow-offs. • Determine weighting factors for applying performance criteria for condition assessment.	Hi	8
	4	Incorporate condition assessment in risk analysis	• Develop methodology to include condition assessment data on pipe assets in risk analysis • Develop guidance manual for utility managers to analyze risk to pipe assets using condition assessment information	Hi	13

Group #	Project #	Research Area/Research Project	Objectives	Ranking	Score
	5	Degradation Curves for Buried Assets	• Synthesize knowledge base on buried asset degradation and relationship to water quality and environmental factors • Present knowledge base in the form of decay curves with validation information	Hi	20
	Notes:	• P1 vendor information proprietary. Blind studies. • P1: Need a system that can be kept up to date.P2 and 5 could be combined (above/below ground) • Standardized data collection could be project • These projects could be global • P2 and P5 are same as G4P1 (CIP/RR) • P3 is guidance manual including data • P4 could fold into G2P2 (risk management) • P4 overlaps with G4P4 (CIP/RR) • P4: Australia has done a lot of work in this area • P2, P4 and P5 are covered in WERF research projects (SAM Challenge)			
4		**Decision-Making for CIP and R&R**			
	1	Life Expectancy of Different Asset Classes	• Develop life expectancy functions/curves for different asset classes to estimate remaining life of asset • Develop condition rating tools based on available asset attributes, including condition of assets	Hi	19

Group #	Project #	Research Area/Research Project	Objectives	Ranking	Score
	2	Develop a Central Repository of Water Utility Asset Data to Support Maintenance, Repair, Rehabilitation and Replacement (MRRR)	• Collect performance indicators (MRRR as currently defined by IWA) for utility use. • Support the development of life expectancy curves (would feed Decision-making Project #1 – Life expectancy of different asset classes)	Hi	26
	3	Develop Methodologies for Prioritizing System-Wide Water Projects	• Establish the information needed to compare unlike and competing projects • Develop common set of criteria for ranking capital improvement projects and provide prioritization program	Hi	18
	4	Develop Asset Classes Decision Guidelines for Maintenance, Renewal, Replacement and Run to Failure Policies	• Develop criteria for comparing the 4 concepts – MRRR • Relate the 4 concepts to asset class	Hi – Med	3
	Notes:	• Library Web site data: who would maintain, AwwaRF develop? University? • National UK database Main (Large) bwsts could add to it. • Lot of information out there already on P2 but will get more reporting, LA, Henrico Co., • P1, Idea overdue. • P1: G3P2 and P5 considering merging into • P2, WW has database • P2. Get it started with small number first • G4P1. • P4: Overlap with G3P4? • Classify all assets. Need uniform			

Group #	Project #	Research Area/Research Project	Objectives	Ranking	Score
		system.			
5		**AM IT and Data Management**			
	1	To Integrate or Not to Integrate IT in Business Practice of AM	• Define role of IT in Municipal AM Business Processes • Define advantages and disadvantages of IT solutions integration in AM	Hi	3
	2	Evaluating Strategies for Data Creation, Collection, Validation, and Maintenance for AM	• Develop standards for data creation • Develop standards for collection • Develop standards for evaluating the integrity of asset data • Develop methods for maintenance of asset data • Determine potential uses for each data component	Hi	15
	3	Data Dictionary for Buried Assets	• Create a standard database template to support AM decisions for buried assets, listing critical data to collect with recommended field names • Define database hierarchies and relationships required for relating both linear work (pigging) to linear features, and point locations (leak) to linear features	Hi	5
	4	IT Integration Data Model to Support AM	• Identify key data elements and linkages between systems to be integrated to support AM • Determine if elements and linkages identified are scalable to utility size and complexity	Hi	36
	Notes:	• P2 and P3 could be combined • P1 and P4 could be combined • P1: Include Institutional barriers to			

Group #	Project #	Research Area/Research Project	Objectives	Ranking	Score
		integration. • P2: Would address data from AM • Link before AM organization • G5P3 links with G4P5 • P4: Focus on guidance documents and standards • Data/policy issues all in IT/AM • Who should gate keep what data • GIS system to access data • AM software in packages			
6		**Operation and Maintenance Practices**			
	1	Develop Best Maintenance Practice for Water Distribution Assets	• Define distribution system assets to create common definitions • Develop preventive maintenance and corrective maintenance programs for water distribution assets	Hi	37
	2	Identify Powerful Tools to Collect Data from Multiple Sources so that O&M Needs can be Cost Effectively Managed	• Collect data to be used for multiple software applications • Assist agencies to understand the approaches and applicability of different data management techniques	Hi	10
	3	Develop Guidelines to Optimize Inventory and Materials Management	• Minimize inventories as required to support a defined level of service • Use AM tools to cross functional barriers and track and manage inventory	Hi	5
	Notes:	• IS operations to be included. Ambiguous. Operations also owns asset. Operations optimization • Reliability and redundancy criticality could be project.			

Group #	Project #	Research Area/Research Project	Objectives	Ranking	Score
		• G6P1 addresses all issues • Framework			

Proposed Project Concept/Ranking Template
Breakout Group: #1 Project: #1
Name & Affiliation of the Proposers/Break out Group Members:
Madeline Goddard,
Linda Reekie, AWWA Research Foundation
Roy Ramani, Water Environment Research Foundation

Tentative Project Title: AM Implementation Strategies Guidance Document
Objective(s):

1. Investigate and compare AM strategies across utilities sector
2. Develop implementation strategies and guidance adaptable to water utilities of all sizes.

Approach:

1. Benchmark AM strategies (metrics and best practices) in utilities (water, nuclear, power, oil and gas), both US and International, that have demonstrated world class AM.
2. Collect case studies that exemplify ranges of utilities (size and/or complexity), identifying barriers and success factors to provide key characteristics of the implementation strategies.
3. Recommend implementation strategies that are appropriate across utilities.

Rationale:
Currently, implementation strategies utilized in the industry have not been collated and synthesized in one document for use by water utilities.
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):

1. Analyze and synthesize strategies for use of water utilities of all sizes to set guidance.
2. Provide handle on how to implement SAM program in structural incremental phases compatible with long term objectives.
3. Provides best practice, implementation strategy

Total Estimated Project Duration: 18 to 24 months
Estimated Project Cost: $250-300,000
Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements):

Proposed Project Concept/Ranking Template
Breakout Group: #1 Project: #2
Name & Affiliation of the Proposers/Break out Group Members:
Steve Allbee, Environmental Protection Agency
Chris Nielson, Cleveland Division of Water

Tentative Project Title: Key Characteristics of Organizations with Effective Asset Management Programs

Objective(s):

1. Identify models of organization structure that lead to sound AM practices
2. Define required personnel skills and organizational capabilities
3. Develop implementation strategies to integrate AM into organizational practices

Approach:

1. Literature search and identification of lessons learned
2. Compare and contrast industry best practices
3. Articulate organizational model and characteristics of successful AM programs

Rationale:

1. Provide a framework for utilities to evaluate their organizational readiness to proceed with AM.
2. Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):
3. Provide clarity and definition of organizational models
4. Develop a checklist of organizational ingredients required for successful AM
5. Highlights strengths and gaps so AM approach and efforts can be focused and prioritized to help drive change management

Total Estimated Project Duration: 9 months
Estimated Project Cost ($): $200,000
Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements): This will provide a strategy for initiating AM and evaluating organizational capabilities and readiness to proceed.

Proposed Project Concept/Ranking Template
Breakout Group: #1 Project: #3
Name & Affiliation of the Proposers/Break out Group Members:
Scott Haskins, Seattle Public Utilities
Ron Lovan, Northern Kentucky Water District

Tentative Project Title: Level of Service and Metrics Development
Objective(s):
1. Determine standard level of service metrics (indicators of customer and environmental levels of service) for drinking water utilities. Relate to specific customer/stakeholder expectations.
2. Produce guidance and implementation strategies for utilities.

Approach:
1. Literature search and best practice review for metrics and practices.
2. Conduct workshop to include utilities, industry associations and participation research organizations. Achieve industry consensus and common definitions.
3. Develop guidance manual

Rationale:
Asset management and resource decisions need to be informed and driven by an understanding of customer desires for levels of service, clear utility performance, cost and rate impact information.
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):
1. Provides guidance for industry and individual utilities to make informed AM and investment decisions
2. Develops standard metrics and indicators to measure and compare performance on assets, infrastructure, financial, customer and environmental performance

Total Estimated Project Duration: 18 months
Estimated Project Cost: $350,000-400,000
Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements):

Proposed Project Concept/Ranking Template
Breakout Group: #1 Project: #4
Name & Affiliation of the Proposers/Break out Group Members:
Tod Burton, Tualatin Valley Water District
Steve Whipp, United Utilities Water Services

Tentative Project Title: Investigate Policies/Strategies Required to Implement Effective AM Programs
Objective(s):
1. Identify policies required to support AM
2. Once policies are defined, provide guidance on how these can be translated into strategies for implementing AM programs

Approach:
1. Research and define key policy requirements (these will include financial planning and rate structures, accounting, levels of service, risk, health and safety, human resources and sustainability)
2. Provide examples and guidance on key aspects of each policy statement
3. Advise on how policies can then be translated into AM implementation strategies

Rationale:
1. To develop a comprehensive set of policy objectives to help drive AM
2. Definition of policies by the governing body to set framework for implementation of the AM program
3. Provides means of communicating AM plan to internal and external stakeholders.

Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):
1. To assist utilities to develop a consistent framework for AM policies and strategies
2. Provides an inventory of key policy priorities required to build and maintain an AM program
3. Demonstrates commitment to the importance of AM throughout an organization and to stakeholders
4. Could provide national policy framework

Total Estimated Project Duration: 12 months
Estimated Project Cost: $250,000
Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements): Identifying and implementing a comprehensive set of policy objectives is an important prerequisite for developing AM programs.

Proposed Project Concept/Ranking Template
Breakout Group: #2 Project: #1
Name & Affiliation of the Proposers/Break out Group Members:
Greg Heitzman, Louisville MSD
Andrew DeGraca, San Francisco Public Utilities Commission

Tentative Project Title: Risk Identification, Consequences and Mitigation Techniques Associated with Triple Bottom Line Economics.
Objective(s):

1. Identify the types of risk for the water and wastewater industry using TBC methodology.
2. Identify the consequences and impacts to the stakeholders (customers, regulators, board, elected officials).
3. Identify mitigation techniques for the risk categories to meet stakeholder expectations.
4. Develop risk management framework/methodology for utility managers to make effective asset management decisions.

Approach:

1. Literature search on risk identification methods, consequences and mitigation techniques (international and utility review)
   a.) Survey utilities for use of risk management methods (Identify consequences of mitigation methods)
   b.) Identify and document case studies of risk management framework/methodology currently in place.
2. Conduct workshop of utility and industry experts to review and develop the risk types, consequences and mitigation methods and establish a framework for risk management.
3. Beta test the framework/methodology among participating utilities (i.e., simple spreadsheet methodology to assist utilities in risk management planning).
4. Document the risk management framework for use by the water industry.

Rationale:
To improve the decision making process for utility managers to reduce long-term risk exposure (economic, social, environmental) and more reliably meet service level expectations.
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):

1. Improved transparency in decision making process
2. More efficient use of capital (long term)
3. Reduced risk profile for utility
4. Improve environmental sustainability
5. Improved customer and stakeholder advocacy
6. Improved bond ratings

Total Estimated Project Duration: 18 to 24 months
Estimated Project Cost: $250,000 to $350,000. Encourage utility participation in travel, workshop, survey, etc.
Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements):

Proposed Project Concept/Ranking Template
Breakout Group: #2 Project: #2
Name & Affiliation of the Proposers/Break out Group Members:
Stephen J. Gaj, Federal Highway Administration
David Marlow, CWIRO Land and Water

Tentative Project Title: Risk Assessment for High Consequence/Low Probability Events.
Objective(s):
1. Define what high consequence, low probability risks should be considered by utilities
2. Determine how these risks should be assessed (a common framework for analysis and tools for analysis)

Approach:
1. Develop a list of risks through literature review, case studies, and cross-sector review.
2. Develop framework and analytical approach and show how to integrate into decision making.
3. Demonstrate and refine through case studies

Rationale:
There are no standardized guidelines and these type of risks can have a significant impact on utility business.
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):
1. Better management and appropriate design practices.
2. Appropriate levels of risk management and avoidance of impacts to customers, communities, and environment.
3. Demonstrable due diligence, improved bond rating

Total Estimated Project Duration: 18 months:
Estimated Project Cost: $200,000
Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements): Significant to industry as a whole. Important gap in decision making process. This should be understood but isn't.

Proposed Project Concept/Ranking Template
Breakout Group: #2 Project: #3
Name & Affiliation of the Proposers/Break out Group Members:
Jeremy Bloom, Electric Power Research Institute (EPRI)
Gary Naumick, American Water Works Service Company, Inc.

Tentative Project Title: Measuring and Using Customer Attitude about Risk.
Objective(s):

1. Develop and quantify a set of customer risk metrics. Engage stakeholders (e.g., Utility management, regulators) in the development of these metrics.
2. Develop a tool a water utility can use to trade off risks vs. mitigation costs.

Approach:

1. Literature review of previous work in the field (AwwaRF customer surveys; work from other industries).
2. Design, administer and analyze a national survey to gather customer attitude toward specific examples of physical risk (e.g., disruption of service, chemical spill, etc.)
3. Develop a tool to allow a utility to analyze reductions of specific risks vs. mitigation costs incurred.

Rationale:
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):

1. In order to effectively manage risks and prioritize expenditures among competing priorities, utilities need to understand how customers value risk and risk mitigation.
2. Tool for utility boards and senior management to determine level of support for investments for risk mitigation.
3. Improved decision making/better risk mitigation. Improved efficiency of invested capital.
4. Teach utility how to conduct and utilize integrated planning, collecting information from their customers and comparing with benchmark data from this study.

Total Estimated Project Duration:

- Phase I – literature research, 4 to 6 months.
- Phase II – Survey, 12 months
- Phase III – Risk analysis tool, 12 months

Estimated Project Cost ($):

- Phase I – ~$50,000
- Phase II – $200,000 survey; $100,000 analysis of survey
- Phase III – $200,000

Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements):

Proposed Project Concept/Ranking Template
Breakout Group: #3 Project: #1
Name & Affiliation of the Proposers/Break out Group Members:
Russ Dueck

Tentative Project Title: Validation of Condition Assessment Inspection Equipment for PCCP
Objective(s):
1. Provide utilities with a user friendly list of proven, cost-effective inspection equipment/technology for PCCP
2. Provide uses, limitations/capabilities of inspection technology

Approach:
1. Survey utilities to determine which inspection companies and equipment work or don't work (largely subjective)
2. Perform experiments to validate innovative technologies
3. Research the different types of inspection equipment available (provide means of updating list on a yearly basis)

Rationale:
Many utilities are reluctant to perform condition assessments based on the fact that they aren't comfortable with or trust the technology or analysis of data.
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):
1. Accurate and confident condition assessments for utilities
2. Encouraging better dialogue between utilities and inspection companies
3. One stop shopping for all North American utilities
4. Short term value to subscriber

Total Estimated Project Duration: 30 months
Estimated Project Cost: $300,000
Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements):

AwwaRF# 4002 ASSET MANAGEMENT RESEARCH NEEDS ROADMAP

Proposed Project Concept/Ranking Template
Breakout Group: #3 Project: #2
Name & Affiliation of the Proposers/Break out Group Members:
Stephen Tucker, Los Angeles Department of Water and Power
Russ Dueck

Tentative Project Title: Develop Degradation Curves For Aboveground Assets (pumps, motors, valves) Including Facilities
Objective(s):
Develop a formula which incorporates environmental conditions to determine remaining expected life for the asset
Approach:

1. Survey utilities to determine the factors leading to degradation of aboveground assets
2. Provide supporting empirical data and demonstrations to fill any information gaps that the utility survey does not provide
3. Literature search of any existing studies that could be used in the determination of degradation curves

Rationale:
Utility managers don't currently have a tool or formula that can be used to predict the remaining life of an asset after it has been assessed.
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):

1. Allow utilities to determine the remaining expected life of pumps, valves and motors
2. Could lead to improvement in pumps, valves, etc. by manufacturers
3. Would help to refine the replacement forecast for aboveground assets

Total Estimated Project Duration: 24 months
Estimated Project Cost: $250,000
Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements):

Proposed Project Concept/Ranking Template
Breakout Group: #3 Project: #3
Name & Affiliation of the Proposers/Break out Group Members:
Todd Petrie, City of Clearwater
Tom Ries, City of Aurora

Tentative Project Title: Condition Evaluation of Water Main Appurtenances
Objective(s):

1. Define and develop performance criteria for water main appurtenances/hydrants, valves, PRVs, service lines, air release valves and blowoffs
2. Determine weighting factors for applying performance criteria for condition assessment

Approach:

1. Survey assessment practices among US and international water utilities and in other applicable industries (oil, gas, chemical, etc.)
2. Determine most applicable criteria for water main appurtenances and provide weighting for each criteria based upon common environmental factors
3. Develop an evaluation matrix from the resulting information

Rationale:
No standardized criteria or methodology exists for condition assessment of water main appurtenances.
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):

1. Assist utilities with identifying appropriate appurtenance performance criteria
2. Assist utilities with developing appropriate maintenance activities
3. Helps ensure ISO compliance
4. Provide common criteria for benchmarking

Total Estimated Project Duration: 24 months
Estimated Project Cost: $150,000
Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements):

Proposed Project Concept/Ranking Template
Breakout Group: #3 Project: #4
Name & Affiliation of the Proposers/Break out Group Members:
Russ Dueck, City of Calgary Water Resources

Tentative Project Title: Incorporate Condition Assessment in Risk Analysis
Objective(s):

1. Develop methodology to include condition assessment data on pipe assets in risk analysis
2. Develop guidance manual for utility managers to analyze risk to pipe assets using condition assessment information

Approach:

1. Evaluate methodologies for condition assessment, risk analysis and how to apply them in utility decision making
2. Perform case studies to validate methodologies
3. Synthesize condition assessment and risk analysis methods to create a manual of procedures to be used by utility managers

Rationale:
Risk analysis requires information on probability and consequence of failure. Estimating probability requires information on condition of assets.
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):

1. Gain realistic probability in final risk analysis
2. Give decision makers more confidence in risk analysis at the point of decision

Total Estimated Project Duration: 18 months
Estimated Project Cost: $250,000
Ranking:
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements):

Proposed Project Concept/Ranking Template
Breakout Group: #3 Project: #5
Name & Affiliation of the Proposers/Break out Group Members:
Neil Grigg, Colorado State University

Tentative Project Title: Degradation Curves For Buried Assets
Objective(s):

1. Synthesize knowledge base on buried asset degradation and relationship to WQ and environmental factors
2. Present knowledge base in the form of decay curves with validation information

Approach:

1. Survey and synthesize knowledge base of buried asset degradation
2. Compile degradation curves by type of buried asset. Test on panel of experts in a workshop
3. Design and present report to display knowledge base and strategy validation

Rationale:
While research has identified causes of pipe failure, additional knowledge is needed of rate of decay of all buried assets, including different types of pipes and appurtenances. This information is needed to plan maintenance, repair and rehabilitation.
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):

1. Provide decision information for utilities on time to failure and serviceability of buried assets
2. Optimize rate-of-return from investments in repair, rehabilitation and replacement
3. Minimize risk of failure of buried assets

Total Estimated Project Duration: 36 months

- Phase I – Synthesize knowledge base
- Phase II – Compile and test compilation of decay curves
- Phase III – Prepare final report

Estimated Project Cost: $150,000
Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements):

Proposed Project Concept/Ranking Template
Breakout Group: #4 Project: #1
Name & Affiliation of the Proposers/Break out Group Members:
Tony Marcum, City of Bellevue
Yakir Hasit, CH2M Hill

Tentative Project Title: Life Expectancy of Different Asset Classes
Objective(s):

1. Develop life expectancy functions/curves for different asset classes to estimate remaining life of asset
2. Develop condition rating tools based on available asset attribute, including condition of assets

Approach:

1. Conduct literature review on past documents on life expectancy
2. Develop preliminary life expectancy functions
3. Utilize and synthesize data collected in Project #2 to enhance preliminary functions
4. Using factors affecting life expectancy and conditions, develop condition rating matrix for use at utility

Rationale:
Utilities have very limited knowledge on the remaining service life of their assets.
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):

1. Provide utilities with a set of standardized life expectancy curves that can be used for estimation of remaining service life
2. Allow utilities to determine the relative condition of the assets for use in asset repair, rehab and replace decisions
3. Reduce asset failure and impact on customers. Provide input to long term planning tools.

Total Estimated Project Duration: 30 months

- Phase I – Life expectancy functions – 18 months
- Phase II – Condition rating tool – 12 months

Estimated Project Cost: $300,000

- Phase I - $200,000
- Phase II - $100,000

Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements):

Proposed Project Concept/Ranking Template
Breakout Group: #4 Project: #2
Name & Affiliation of the Proposers/Break out Group Members:
Annie Vanrenterghem-Raven, Polytechnic University, New York
Mark Kattenbert, Greater Cincinnati Water Work

Tentative Project Title: Develop a Central Repository of Water Utility Asset Data to Support MRRR Decision Making

Objective(s):

1. Collect performance indicators (MRRR, currently defined by IWA) for utility use
2. Support the development of life expectancy curves (would feed Decision Making Project #3 – Life Expectancy of different Asset Classes)

Approach:

1. Define the performance indicators that can be shared by utilities
2. Develop Web-based database and utility input process
3. Analyze data relevant to the development of life expectancy curve
4. Develop display and output of data for utility use and include training sessions

Rationale:
This is not available in the US but is currently developed for use by other countries (i.e., Portugal). Allows utilities to learn from each other's experience and data.

Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):

1. Benefits utility for development of CIP programs
2. Gives utility a tool to sell (justify) CIP program to regulatory boards and customers

Total Estimated Project Duration: 24+ Months

- Phase I – Develop process, partners, database and collect data – 2 years
- Phase II – Maintenance – Continual

Estimated Project Cost: $300,000+

- Phase I – $300,000
- Phase II – $100,000/year (money could be generated by users of the repository)

Ranking: Hi

Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements): Sets up opportunity for utilities to learn from each other and pool data together to generate information that can be shared by everyone.

Proposed Project Concept/Ranking Template
Breakout Group: #4 Project: #3
Name & Affiliation of the Proposers/Break out Group Members:
Amy Kramer, Northern Kentucky Water District
Jim Chelius

Tentative Project Title: Develop Methodologies for Prioritizing System-wide Water Projects
Objective(s):

1. Establish the information needed to compare unlike and competing projects
2. Develop common set of criteria for ranking capital improvement projects and provide prioritization program

Approach:

1. Phase I
    a. Survey utilities (transportation, water, sewer, gas and electric) to determine decision making methods being used
    b. Assess tools available or needed to facilitate process
    c. Interview candidates to document practices
2. Phase II
    a. Develop methods and criteria for prioritizing water projects
    b. Conducts test cases to verify methodologies
    c. Prepare report describing methodology

Rationale:
Utilities are faced with the challenge of determining which projects are most important to fund with a limited amount of resources.
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):

1. Defend decisions (on how to spend money) to internal (staff, management, board) and external (rate payers, rate commission) customers
2. Provide standard approach across utility/industry for prioritizing projects

Total Estimated Project Duration: 48 months

- Phase I – 18 months
- Phase II – 30 months

Estimated Project Cost: $450,000

- Phase I - $150,000
- Phase II - $300,000

Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements):

Proposed Project Concept/Ranking Template
Breakout Group: #4 Project: #4
Name & Affiliation of the Proposers/Break out Group Members:
Jim Kummer, St. Louis Water Division
Michael Hooker, Onandaga County Water Authority

Tentative Project Title: Develop Asset Classes Decision Guidelines for Maintenance Renewal, Replacement and Run to Failure Policies

Objective(s):

1. Develop criteria for comparing the four concepts: maintenance, renew, replace and RTF
2. Relate the four concepts to asset class

Approach:

1. Identify universal asset classes (relative to majority of utilities) (i.e., underground vs. aboveground)
2. Survey utilities with respect to their approach to asset management with respect to employment of the four concepts (MRRR, RTF)
3. Develop a comparison matrix (marriage of concepts and survey results)

Rationale:
Develop a common framework for utilities to draw from for comparing their organizations' AM efforts to an industry "standard".

Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):

1. Validation of current AM practices (or support reasons for change)
2. Set process in motion to establish industry standards for contrast and comparison, ultimately leading to benchmarking metrics
3. Provide managers with the tools needed to convince decision makers (boards, government, etc.) and the public about the need for and benefits of well developed asset management programs.

Total Estimated Project Duration: 7 months

- Phase I – Asset Management class identification – 1 month (literature search, small sample of systems)
- Phase II – Survey of utility practices – 3 months
- Phase III – Develop practices matrix for asset classes and utility input – 3 months
- Phase IV – Workshop to validate AM matrix
- Estimated Project Cost: $107,500
- Phase I - $5,000
- Phase II - $15,000
- Phase III - $20,000
- Phase IV - $67,000

Ranking: Hi – Med

Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements): Group split based on their specific interests

Proposed Project Concept/Ranking Template
Breakout Group: #5   Project: #1
Name & Affiliation of the Proposers/Break out Group Members:
Marc Cottingame, Dallas Water Utilities
Dennis Dickerson, Columbus Department of Public Utilities

Tentative Project Title: To Integrate or Not to Integrate IT in Business Practice of AM.
Objective(s):
1. Define role of IT in Municipal AM Business Processes
2. Define advantages and disadvantages of IT solutions integration in AM

Approach:
1. Survey IT Asset Management systems integration experiences among US and International Water and Wastewater Utilities and other industries.
2. Develop appropriate measures and matrix model based on scale (size) of utility or industry and/or multiple IT asset management solutions.
3. Develop report and guidance document with scaled assessment of integration practices of asset management IT solutions.

Rationale:
Integration of Asset Management IT solutions with constant versioning and custom applications can be costly and consume limited IT resources.
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):
Trend activities in the industry.
1. Set some guidelines to assist making IT integration decisions.
2. Set roadmap for utility IT Asset Management integrations

Total Estimated Project Duration:
- Phase I – 6 months (Survey)
- Phase II – 9 months (report/guidance document)

Estimated Project Cost:
- Phase I -- $200,000
- Phase II -- $300,000

Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements): Decisions on IT asset management integrations are occurring with no industry guidance or standardization. May present savings to utilities and set BMP for asset management IT solutions integration.

Proposed Project Concept/Ranking Template
Breakout Group: #5 Project: #2
Name & Affiliation of the Proposers/Break out Group Members:
Joel Johnson, Advantica
Dennis Dickerson, Columbus Department of Public Utilities
Dean Rurak, Region of York

Tentative Project Title: Evaluating Strategies for Data Creation, Collection, Validation, and Maintenance for AM.

Objective(s):

1. Develop standards for data creation
2. Develop standards for collection
3. Develop standards for evaluating the integrity of asset data
4. Develop methods for maintenance of asset data
5. Determine potential uses for each data component

Approach:

1. Survey representative water and wastewater utilities to determine current practices for data creation, collection, validation, maintenance, and analysis.
2. Inventory and evaluate existing industry data models.
3. Contact regulatory agencies for pending regulations and anticipated data needs.
4. Develop a standard data model that can be modified and scaled for individual utilities.

Rationale:
There is no current comprehensive standard practice or guideline for data creation, collection, evaluation, and maintenance. There is also no practical evaluation tool for utilities to determine what data to collect and how to use it.

Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):
Develop a consistent standard that integrates data creation, collection, validation and maintenance.

1. Assist utilities in turning data into knowledge.
2. Increase confidence in decision making and data reporting to regulatory and funding agencies.

Total Estimated Project Duration: 12 months
Estimated Project Cost: $225,000
Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements): Data management is an essential component of the asset management paradigm. A best practice for the creation, collection, validation, and maintenance of data will enable utilities to move their own data management practices forward.

Proposed Project Concept/Ranking Template
Breakout Group: #5 Project: #3
Name & Affiliation of the Proposers/Break out Group Members:
Maureen Hodgins, AWWA Research Foundation
Chris Saill, Westin Engineering

Tentative Project Title: Data Dictionary for Buried Assets.
Objective(s):

1. Create a standard database template to support AM decisions for buried assets, listing critical data to collect with recommended field names.
2. Define database hierarchies and relationships required for relating both linear work (pigging) to linear features, and point locations (leak) to linear features.

Approach:

1. Review national and international data sets to determine data currently being captured and most typical naming conventions.
2. Determine which data fields required to make asset management decisions both real time and predictive, by surveying utilities.
3. Review with developers (e.g., ESRI, etc.) to determine best typical approach.

Rationale:
Help utilities doing IT upgrades to maximize the potential for asset management.
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):

1. Help utilities with limited historical data.
2. Avoid missteps during system upgrades

Total Estimated Project Duration: 24 months
Estimated Project Cost: $200,000
Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements): Major system replacements are occurring with more regularity. This report would complement specifications to support asset management best practices.

Proposed Project Concept/Ranking Template
Breakout Group: #5 Project: #4
Name & Affiliation of the Proposers/Break out Group Members:
Kurt Vause, Anchorage Water & Wastewater Utility
Heather Pennington, Tacoma Public Utilities

Tentative Project Title: IT Integration Data Model to Support AM.
Objective(s):
1. Identify key data elements and linkages between systems to be integrated to support AM
2. Determine if elements and linkages identified are scalable to utility size and complexity

Approach:
1. Survey of leading enterprise asset management solutions providers to determine current market state.
2. Identify within leading utilities their degree of success in ongoing integration efforts and existing gaps.
3. Summarize key data elements and system components essential for asset management paradigm
4. Develop report of findings with an idealized and scalable integration data model.

Rationale:
Presently, no guidance regarding key elements to be brought together based on size and scope of an individual utility. To avoid a piecemeal method the research on elements and linkages will identify the pathway.
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):
1. Serve as a summary of what to integrate to optimize integration efforts, minimize costs, minimize future reconfiguration and streamline timeline for integration efforts.
2. Enhance asset management analysis capabilities.
3. Identify whether integration is scalable to avoid procurement of a system which is wrong fit.

Total Estimated Project Duration: 12 months
Estimated Project Cost: $185,000
- Phases I and II: $40,000
- Data Model Development: $60,000
- Analysis: $60,000
- Report Writing: $25,000

Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements): Data integration is essential to support development of an asset management program. This data model and determination of scalability will facilitate accelerated integration efforts and prevent false starts, and inappropriate integration.

Proposed Project Concept/Ranking Template
Breakout Group: #6 Project: #1
Name & Affiliation of the Proposers/Break out Group Members:
Arthur Petrini, Henrico County DPU
Charles Kiely, District of Columbia Water and Sewer Authority

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Tentative Project Title: Develop Best Maintenance Practices for Water Distribution Assets
Objective(s):
1. Define distribution system assets to create common definitions
2. Develop preventive and corrective maintenance programs for water distribution assets

Approach:
1. Survey water utilities to determine what they consider distribution assets
2. Survey and assess water utilities for their preventive and corrective maintenance practices for distribution assets
3. Develop best management practices for distribution systems assets by consensus of experts in the field through workshops and reports

Rationale:
Few utilities have defined water distribution assets and none implemented best management practices
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):
1. Standardization of distribution system assets
2. Allows utilities to implement best management practices for distribution systems assets
3. This will improve reliability, efficiency, productivity, cost-effectiveness and service to the customers

Total Estimated Project Duration: 18 months
Estimated Project Cost: $300,000
Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements):
1. Distribution assets are largest financial components
2. No standards exist
3. Impact customer service levels
4. Critical need

Proposed Project Concept/Ranking Template
Breakout Group: #6 Project: #2
Name & Affiliation of the Proposers/Break out Group Members:
Isaac Pai, Long Beach Water Department
Terry McGhee, DuPage Water Commission

Tentative Project Title: Identify Powerful Tools to Collect Data From Multiple Sources so That O&M Needs Can be Cost-Effectively Managed

Objective(s):

1. Collect data to be used for multiple software applications
2. Assist agencies to understand the approaches and applicability of different data management techniques

Approach:

1. Survey assessment practices among US and International utilities and other industries
2. Define formats to minimize data entries. Define data parameters and fields to be collected
3. Identify compatible software (CMMS, GIS, etc.) so that the same data source can be commonly used

Rationale:
To better assist water agencies to more easily implement EO&M needs.

Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):

1. Minimize redundant data entries
2. Assist agencies to identify compatible software
3. Present case studies to assist agencies to identify benchmark metrics

Total Estimated Project Duration: 12 months
Estimated Project Cost: $100,000
Ranking: Hi
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements): To assist agencies to plan and buy the right compatible software rather than investing the money and time, but only to realize there are many other important experience factors that others had gained.

Proposed Project Concept/Ranking Template
Breakout Group: #6 Project: #3
Name & Affiliation of the Proposers/Break out Group Members:
Lisa Toth,
Chris Harder, Fort Worth Water

Tentative Project Title: Develop Guidelines to Optimize Inventory & Materials Management
Objective(s):

1. Minimize inventories as required to support a defined level of service
2. Use AM tools to cross functional barriers and track and manage inventory

Approach:

1. Survey utilities on inventory management practices
2. Develop risk/level of service standards for critical systems/facilities/assets. Provide rationale for decision making. Align with service levels out of other projects.
3. Develop guidelines for an inventory management system that meets pre-determined level of service requirements

Rationale:
There is a tendency of utilities to accumulate excessive inventories. There is a lack of literature devoted to public sector utilities related to inventory control.
Benefits/Industry Value (to utilities, regulators, industries and other stakeholders):

1. Avoids duplication/excess inventory, resulting in cost savings
2. Documents required level of service and inventory requirements
3. Increases reliability by documenting needs

Total Estimated Project Duration: 12 months
Estimated Project Cost: $150,000
Ranking: Med
Reasoning/Criteria (e.g., Significance to industry as a whole, urgency, support meeting regulatory requirements): Was not ranked high due to lack of urgency or regulatory requirements. However, could result in substantial cost savings.

APPENDIX C

CASE STUDIES

APPENDIX C
CASE STUDIES

This Appendix contains the following Case Study write-ups:

- American Water – Voorhees, New Jersey
- Anchorage Water and Wastewater Utility – Anchorage, Alaska
- Charleston Water System – Charleston, South Carolina
- District of Columbia Water and Sewer Authority – Washington, DC
- DuPage Water Commission – Elmhurst, Illinois
- Henrico County Department of Public Utilities – Richmond, Virginia
- Long Beach Water Department – Long Beach, California
- Los Angeles Department of Water and Power – Los Angeles, California
- Louisville Water Company – Louisville, Kentucky
- Newport News Waterworks – Newport News, Virginia

These case studies are snapshots of the status of asset management (AM) at the respective utility at the time the case study was prepared. Case studies were prepared by a member of the project team with major input from the staff at the utility. The normal sequence of conducting the case study was to request key background information, meet with the utility staff to discuss the AM program, prepare a draft case study for utility review, and finalize the case study based on the comments received. Some case studies include descriptions of both drinking water and wastewater AM programs. Before inclusion in this report, the utility contact signed off on the acceptability of publishing the final case study. The type of information that was initially requested is presented at the beginning of Appendix C.

October 5, 2006
Name
Utility
Address
City, State Zip

RE: Case Study for AwwaRF Asset Management Research Needs Road Map Project (AwwaRF # 4002)

Dear (Your Contact at Utility):

HDR and Westin Engineering, Inc. (Westin) are beginning the Case Study portion of the AwwaRF project Asset Management Research Needs Road Map.

As part of your participation in this project, your utility determined that it would be advantageous to be a subject of a Case Study. These case studies are intended to document the current state of utility asset management practices at a cross-section of water and wastewater utilities throughout North America. This foundation is an important element in prioritizing the industry-wide needs for research into asset management.

This part of the project includes:

- Reading and completing the brief questionnaire on the following pages as best you can.
- Returning the questionnaire to (Your Name) of HDR at (Your Address) or (Your Email). If you have documents prepared that already describe in part or whole your asset management program, please provide us a copy with the questionnaire.
- HDR and/or Westin will then follow up with a personal interview and/or site visit at your convenience.
- HDR and Westin will prepare Case studies as part of the project deliverable

On behalf of HDR and Westin, we would like to express our appreciation for your involvement, and your efforts to help make this study successful. If you have any questions or concerns, please contact (Your Name) at HDR at (Your Phone Number) or Doug Spiers of Westin at (916) 852-2111. Thank you in advance for your assistance with this valuable undertaking.

Sincerely,

Your Name	Doug Spiers, P.E., Esq.
Your Title	Project Manager
HDR Engineering, Inc.	Westin Engineering, Inc.

Questionnaire

The Asset Management Questionnaire includes the following areas of Enterprise Asset Management analysis as representative of required activities within a "mature" asset management program.

- Demographics
- Organizational
- Asset Record
- Work Order
- Preventive / Predictive Routine
- Inventory Control
- Asset management Practices
- Asset Inspection
- Condition Assessment
- Rehabilitation and Replacement

This questionnaire is based upon the International Infrastructure Management Model for lifecycle asset management as depicted below. This model outlines the necessary activity, from creation to eventual retirement, to ensure the best return on asset reliability and capital investment.

Demographics

Provide the information for your direct service area or where you implement full service.

Question 1. What is the current size of the water utility?

Avg. MGD Treated or Delivered __________

Peak MGD Treated or Delivered __________

Total Rated Treatment Capacity MGD __________

Question 2. What is the current size of the wastewater utility?

Avg. MGD Treated or Conveyed __________

Peak MGD Treated or Conveyed __________

Total Rated Treatment Capacity MGD __________

Question 3. What is the number of water customers of your Utility? (Direct Service)

Water Connections __________

Population Served __________

Question 4. What is the number of wastewater customers of your Utility? (Direct Service)

Wastewater Connections __________

Population Served __________

Organizational Analysis

Question 5. How many people are employed by your Utility? ________ FTEs

Question 6. Are your Asset Management Goals and Objectives defined in writing? ☐Yes ☐No

Question 7. Are your Asset Management Goals and Objectives adequately communicated and understood by the appropriate Utility staff? ☐Yes ☐No

Question 8. Do you have a designated "Asset Manager" in charge of your Asset Management Program?

☐Yes ☐No Name: ______________________________

Question 9. If the answer to Question 8 is "NO," who in the Utility Organization makes asset management decisions?

Title: ______________________________

Title: ______________________________

Title: ______________________________

Asset Record

Question 10. Does each asset have a formal and unique asset identification code? ☐Yes ☐No

Question 11. Is the asset identification scheme consistent throughout your Utility? ☐Yes ☐No

Question 12. Are there formalized and consistent hierarchies of assets, e.g., parent-child relationships?

☐Yes ☐No

Question 13. Are assets prioritized by cost and/or process criticality? ☐Yes ☐No

Work Order Analysis

Question 14. Are asset histories (work orders) recorded into a maintenance management system?

☐Yes ☐No

Question 15. What Maintenance Management Software is employed?

______________________________ (Name) __________ (Year of Last Upgrade)

______________________________ (Name) __________ (Year of Last Upgrade)

______________________________ (Name) __________ (Year of Last Upgrade)

Question 16. Are labor hours tracked to each work order? ☐Yes ☐No

Question 17. Are associated material costs recorded to each work order? ☐Yes ☐No

Question 18. Are asset histories (work orders) readily available for review and analysis? ☐Yes ☐No

Question 19. Are maintenance reports automatically generated? ☐Yes ☐No

Question 20. Can asset history (work orders) be cross-referenced by processes, functions or types of assets? ☐Yes ☐No

Question 21. Does the Utility effectively utilize the existing maintenance management software?

☐Yes ☐No

Preventive and Predictive Maintenance Analysis

Question 22. Does your Utility generally perform the appropriate level of Preventive Maintenance?

☐Yes ☐No

Question 23. Does your Utility generally perform the appropriate level of Predictive Maintenance?

☐Yes ☐No

Question 24. Does your Utility perform Reliability Centered Maintenance? ☐Yes ☐No

Question 25. What percentage of the work orders are reactive in nature (service requests, breaks, emergency repair) as compared to preventive or predictive? _____% Reactive Based on: ☐Hours ☐$

Question 26. Are preventive maintenance work orders usually automatically initiated from your maintenance management software? ☐Yes ☐No

Question 27. Are preventive maintenance work orders generally completed on schedule? ☐Yes ☐No

Question 28. Are preventive maintenance completion rates routinely reported to management?

☐Yes ☐No

Question 29. Are the root cause of failures identified, tracked and analyzed? ☐Yes ☐No

Question 30. Are predictive maintenance techniques routinely utilized? ☐Yes ☐No

Inventory Analysis

Question 31. Is inventory appropriately controlled? ☐Yes ☐No

Question 32. Are spare parts and equipment generally available in stock? ☐Yes ☐No

Question 33. Are critical stock items separately identified and maintained? ☐Yes ☐No

Asset Inspection Analysis

Question 34. Is the condition of your above ground infrastructure adequately documented and maintained? ☐Yes ☐No

Question 35. Is the condition of your below ground infrastructure adequately documented and maintained? ☐Yes ☐No

Asset Management Analysis

Question 36. Is the value of the Utility assets known?

a. Installed Value ....☐Yes ☐No
b. Book Value ....☐Yes ☐No
c. Replacement Value ....☐Yes ☐No

Question 37. Is the Utility using the GASB 34 Modified Approach? ☐Yes ☐No

Question 38. Is critical asset performance routinely analyzed? ☐Yes ☐No

Question 39. Is Life-Cycle cost analysis performed? ☐Yes ☐No

Question 40. Are Capital Improvement Projects (CIP) the direct result of Asset Performance and Life-Cycle-Cost Analyses? ☐Yes ☐No

Question 41. Do Root Cause Failure Analyses and Failure Modes and Effect Analyses drive asset engineering design or improvement projects? ☐Yes ☐No

Asset Rehabilitation and Replacement Analysis

Question 42. Has your organization developed and implemented a strategic Replacement and Rehabilitation (R&R) planning program? ☐Yes ☐No

Question 43. Are key decision points adequately defined for R&R? ☐Yes ☐No

Question 44. Is the Utility spending the appropriate amount of R&R dollars to maintain the appropriate or designated level of service? ☐Yes ☐No

Closing

Question 45. What is the most important change the Utility should make to improve its current Asset Management Program?

QUESTION 46. PLEASE PROVIDE ANY OFF THE SHELF REPORTS OR DESCRIPTIONS THAT DESCRIBE YOUR ASSET MANAGEMENT PROGRAM.

ASSET MANAGEMENT CASE STUDY: AMERICAN WATER

I. UTILITY PROFILE

American Water serves approximately 15 million people through over 600 water and wastewater systems throughout the country. Approximately 7,000 full-time employees are employed by the company. American Water operations consist mainly of drinking water utilities; less than 5% of the systems involve wastewater collection and treatment. Over 120 years, American Water has acquired many of the systems it now owns.

American Water drinking water systems treat and deliver an average of 1,380 million gallons per day (MGD) and a peak of 2,000 MGD to approximately 3.1 million customers in 18 states. The wastewater systems treat and convey an average of 50 MGD with a total rated capacity of 90 MGD. There are 135,000 sewer connections, serving a total population of approximately 350,000 people in 10 states.

Gary Naumick is the Director of Capital Program Management/Asset Planning and Strategy for American Water, and can be reached by e-mail at Gary.Naumick@amwater.com or by phone at 856-346-8249. Asset planning and asset management are managed at the corporate level under Gary's direction with significant input from local staff regarding capital planning decisions.

II. DEFINED ASSET MANAGEMENT PROGRAM GOALS

American Water's asset management program goals are to maximize the life of infrastructure assets, ensure that the asset continues to provide benefits to customers, and to make cost-effective decisions regarding the creation/acquisition, operation, maintenance, rehabilitation, renewal, or disposal of its assets.

III. HISTORY AND STATUS OF ASSET MANAGEMENT PROGRAM

Asset Inventory and Hierarchies

American Water owns and operates many systems across the country, some of which it acquired from other utilities where asset information was not consistently organized or identified and others where informal systems were in place.

A financial database is the primary form of centralized asset management currently used by American Water. The financial database is standardized company-wide and is organized by location and type of asset. It contains information relating to the location, economic life, and depreciation of each asset. Information regarding asset condition, criticality, and service history is maintained locally. Asset naming is standardized within the financial database. System asset numbering and identification schemes vary across the company and the need for a standardized system is recognized. Individual American Water districts vary in methods of maintaining asset inventory. For example, American Water complies with many state regulations that require a breakdown of pipe material and size.

Several systems within American Water have developed local asset databases, some of which have implemented the asset management system, Datastream 7i. This system is being considered for other American Water subsidiaries along with other potential software solutions as American Water standardizes its approach to asset maintenance. Through this program and New Jersey American's implementation of the geographic information system (GIS), naming and identification conventions utilized by local asset databases will be standardized as GIS becomes more widely implemented and integrated company-wide.

Condition Assessment

Condition assessment of critical assets is performed by field personnel as a part of day-to-day routines. It is usually tracked in paper form, although there is a growing trend within the company to use electronic devices such as palm pilots and computer toughbooks employed by field service representatives. Generally, the company considers pumps, motors, and plant operating equipment to be critical assets, and collects and maintains data on the condition and maintenance history of these assets. There is reliance on local knowledge of operating systems to identify and report on the status of capital assets in need of renewal or replacement through the capital planning program. However, there is not currently a uniform assessment methodology or a formal program for condition comparison among assets. Capital planning staff, with use of a prioritization modeling tool, make the effort to assess the comparative value and timing of improvements proposed within the capital budgeting program. Condition assessments of non-critical infrastructure are not currently documented in a formal manner.

American Water is currently implementing use of a proactive leak detection and reporting system at the customer service level. The proactive leak detection system finds leaks acoustically, often before they surface. By identifying leaks early, the company can repair or replace water lines prior to suffering extensive water loss or before leaks cause extensive damage. By mitigating the consequences of failure through this and other programs such as pressure reduction, cathodic protection, and maintenance programs, the life of many assets can be extended.

Maintenance Management

American Water generally performs preventive maintenance on its most critical assets in a large majority of its systems. Completion of preventive maintenance is routinely reported to management. American Water also performs reliability-centered maintenance.

Asset maintenance history is usually tracked in paper form, which prevents a standard analysis of asset histories. As a result, there is heavy reliance on communication through staff on identifying key capital projects. Those systems that employ Datastream 7i for local asset management have started using the program to capture maintenance history through work orders.

Purchasing and Inventory Management

American Water has two steps in its strategy for purchasing assets: first, the utility makes specific decisions on uniform materials and products; second, the utility uses national procurement strategies. American Water has a competitive list of material vendors. Following a thorough assessment of product and service capabilities, a preferred list is prepared and updated annually. The utility is currently developing a national-level buried asset detail document for uniformity of purchasing. Some assets that American Water utilizes are leased. Asset inventories are managed at district levels. Districts separately identify and maintain critical stock items.

Use of IT Solutions

As discussed previously, American Water does not currently have an integrated, centralized asset database other than the financial database. Several of the subsidiaries of American Water are utilizing Datastream 7i for management of local assets. Most American Water utilities rely on supervisory control and data acquisition (SCADA) systems to monitor operations in the system. The level of sophistication varies from system to system based on the complexity of the water system facilities. There is currently no standard program for EAMS maintenance throughout the company, although it is used at some locations. GIS integration utilizing ESRI products is being implemented at some systems including those in New Jersey, Tennessee, Arizona, and California. With the onset of an extensive GIS implementation in New Jersey, a standardized model is being implemented to facilitate conversion by the entire company over time.

Capital Renewal & Replacement Planning; Life-Cycle Costing Model

American Water has a formal decision process for asset rehabilitation and replacement (R&R). Historically, the utility has focused more on asset replacement for buried assets as opposed to rehabilitation. The business plan for the next five years includes an increasing amount of money available for R&R to maintain sustainability of service.

The Capital Improvements Program (CIP) focuses on needed improvements. There is a rigorous review process in place that integrates company strategy and priorities for spending and the needs of local systems as determined from hydraulic models, overall plant conditions, and plant component conditions. Projects are prioritized by criticality and a five-year plan is created, with projects updated quarterly. Other capital money is generally available to support unplanned or emergency requirements.

Renewal versus replacement of an asset is determined by a life-cycle cost analysis on a case-by-case basis. Risk is frequently an overriding factor as opposed to economic life-cycle retention when the decision for replacement is made. American Water has determined over the years that replacement is normally the best form of renewal for below-ground infrastructure. This is because the utility is often forced to renew the entire road surface even when disturbance is minimized by rehabilitation methods. Renewal of aboveground infrastructure is evaluated more closely versus replacement. American Water uses future growth projections and hydraulic models to help determine whether an asset should be abandoned because it is no longer required or whether it is uneconomical to maintain or rehabilitate. Water distribution system models are uniform and exist for nearly all systems to aid in evaluating hydraulic issues.

Valuation and Depreciation Methodology

American Water tracks the installed value of its assets through the financial management system; the book value and replacement value of assets is not currently known. American Water is a private utility; therefore, GASB-34 implications are not required but are implemented internally as business accounting practices. Capital Improvement Projects are the direct result of life-cycle cost analyses. Since Root Cause Failure Analyses and Failure Modes and Effect Analyses are not usually performed, their results are not available for asset engineering design or improvement projects.

IV. COSTS, SAVINGS, AND IMPROVEMENTS TO DATE

Asset tracking, such as through the use of Datastream 7i and GIS by some systems, is relatively recent, and there is not a complete performance reporting system in place to track the costs and savings. Costs and savings of the asset management program vary from system to system within American Water and are difficult to document. Standardization of buried assets specifications and other best operating practices related to managing assets to be implemented across the company have been initiated.

V. LESSONS LEARNED

Many of the systems American Water now owns were acquired from other utilities and consequently have different asset nomenclature and practices. American Water recognizes the need for a standardized approach to asset management across all of its systems. Improved decision making on capital expenses can be realized with a standardized approach.

VI. FUTURE PLANNED ASSET MANAGEMENT ACTIVITIES

Planned future activities to improve American Water's asset management system include the following:

- Develop and populate a centralized asset management database, starting with the most critical assets.
- Evaluate, select, and implement software for company-wide maintenance management.
- Produce a methodology to identify critical assets in terms of their function and consequence of failure.
- Standardize asset naming and numbering throughout all systems.
- Capture asset maintenance through work orders consistently across the company.
- Continue to increase spending for rehabilitation and renewal of assets over the next five years.
- Continue implementation of GIS and integration with asset management databases.

ASSET MANAGEMENT CASE STUDY: ANCHORAGE WATER AND WASTEWATER UTILITY

I. UTILITY PROFILE

The Anchorage Water and Wastewater Utility (AWWU) provides water treatment, water distribution, wastewater collection, and wastewater treatment services to a population of more than 270,000 residents in Anchorage, Eagle River, and Girdwood. There are over 54,000 water and sewer connections. The average water treated and delivered is 26 MGD, with a peak of 61 MGD. The total rated treatment capacity is 65 MGD. The average wastewater collected and treated is 31 MGD, with a peak of 56 MGD. The total rated treatment capacity is 61 MGD. The utility staff totals 278 full-time equivalents (FTEs). The utility is made up of several divisions:

- **Engineering:** Design and project management, master planning and facility planning, capital program coordination, GIS
- **Operations & Maintenance:** Operations and maintenance duties for entire utility
- **Treatment:** Operation of treatment plants, water distribution system, wastewater pretreatment program
- **Information Technology:** Information management services for entire utility
- **General Manager:** Managerial oversight and strategic direction
- **Customer Service:** Customer accounts, locates, meters, customer connections
- **Finance:** Financial administration, regulatory affairs, budgeting
- **Employee Services:** Assisting employees with benefits and human resource issues

The utility's contact person for this project is Mr. Kurt Vause, AWWU Engineering Division Director, whose e-mail address is Kurt.Vause@awwu.biz. Mr. Vause's telephone number is 907-564-2779.

II. DEFINED ASSET MANAGEMENT PROGRAM GOALS

The utility's asset management vision is defined as:

"Excellence Through Innovation"
with a mission
"Dedicated to serving our community's public health needs by providing reliable, quality water and wastewater services in an environmentally sound and sustainable manner."

Each element in the vision statement implies specific objectives for AWWU's asset management program. Since this vision's creation, it has provided guidance on asset management matters for AWWU's management team. These objectives are reflected in planning for capital improvements, rehabilitation and replacement priorities, resourcing for preventive maintenance programs, and daily management decisions.

III. HISTORY AND STATUS OF ASSET MANAGEMENT PROGRAM

History

AWWU recently had an evaluation completed on the asset management program employed at the utility. As a utility, AWWU has been working toward identification of improvements in asset management to reduce operating costs, optimize asset use, and improve reliability throughout the system.

Asset Inventory

The asset inventory currently resides in three main systems with different functionality: GIS is the primary system for horizontal infrastructure, Maximo is the primary system for vertical infrastructure, and PeopleSoft is the primary system for the finances of asset acquisitions and retirements. In addition, supplementary systems are used to complete evaluations of the assets, including the hydraulic models and the closed-circuit television (CCTV) program. The utility developed a networked inventory of its water distribution and wastewater collection assets in MWSoft Water and MWSoft Sewer software applications. These models were developed over the last three years, and are currently being used to model flows in each of system.

Over the last 10 years, AWWU has developed an online inventory of its assets and has recently linked that information to one accessible geodatabase. This database includes information such as pipe type, age, and maintenance history of water and sewer lines. This geodatabase covers the systems for Anchorage, Eagle River, and Girdwood. This easy-to-access geodatabase has improved knowledge of the system for operators and engineers alike, improved response time in emergencies, and greatly assisted in maintenance operations and data management.

Assets are also quantified in the utility's Maximo work management application, which provides maintenance prompts for equipment-related assets belonging to the utility. This work order application was fully implemented in 2000 and is in operation today. The work orders generated with this application track preventive, corrective, and emergency maintenance activities associated with AWWU water and sewer systems.

Condition Assessment

For underground wastewater collection assets, CCTV inspection is utilized to record condition data. The utility owns one television inspection vehicle purchased in 1986, supplemented by outsourced inspections completed by local contractors. A digital system (Cues Granite XP) for television inspection data was implemented in early 2006, replacing reliance on the older VHS taped inspection data and improving access to condition information and images. This new system is capable of producing condition assessment reports that can be accessed by engineering or linked to the geospatial database.

Water distribution asset condition data is limited to information that can be inferred from exercising valves, flow testing hydrants, and collecting water quality samples, as well as cathodic protection test status for the major water transmission lines. Cathodic protection activities are recorded by Operations as preventive or as corrective maintenance data in the Maximo application. Main break history (location, cause(s), subsurface conditions, etc.) are also recorded in the Maximo application for planning and analysis.

In treatment plants, the condition of equipment is assessed during regular rounds, but no formal documented process is in place to capture the data. Recently, post-failure reviews of equipment have been performed at the treatment plants.

Maintenance Management

For underground water distribution and wastewater collection assets, the utility is increasing its level of preventive maintenance, outsourcing some of this work in its effort to reach the desired levels.

A thorough preventive maintenance program is in place for the pumping stations. Preventive maintenance work orders are initiated automatically from the Maximo maintenance management software. Preventive maintenance completion is monitored by plant and distribution general foremen and is available electronically for review or query by management. AWWA has discussed input of operation and condition data into Maximo to document conditions as part of preventive maintenance. This may be an option as AWWU upgrades to the new version of the work management application (i.e., Maximo 6.0).

Each plant has its own preventive maintenance program developed specifically for that plant. Plant operators use Maximo to generate and schedule required operational and maintenance work orders, which the facility foreman executes with facility staff or Operations crew. Operations and Treatment staff members have discussed ways to formalize this process and to achieve higher levels of planned maintenance (versus reactive maintenance) work.

A thorough preventive maintenance program is also in place for utility fire hydrants. Preventive maintenance is significant in that numerous maintenance activities occur related to both winter and summer operation of the nearly 7,000 hydrants operated by the utility. Maximo work orders are used to schedule, track, and record maintenance.

In addition, the utility performs preventive maintenance on its fleet of rolling stock consisting of passenger vehicles, heavy construction equipment, boiler trucks, and other maintenance vehicles. Maximo is used to schedule, track, and control work associated with preventive maintenance activities.

In the area of predictive maintenance, the AWWU treatment plants perform limited tracking of equipment performance. Bearing temperatures are monitored on major rotating equipment at several of the treatment facilities. Treatment crews are also capable of monitoring amperage draw from certain pieces of equipment. These are not uniformly monitored or recorded.

Predictive maintenance is also being performed on the distribution and collection system: pipe failures are being predicted in the master planning process based on soil type, pipe type, and pipe duration in the soil. This predictive maintenance can be used to inspect and repair a line prior to its outright failure. Information obtained by field crews on soil resistivities at spot dig locations is kept in database tables that allow the utility to better understand soil conditions at those locations. In addition, specific infrastructure facilities – such as large-diameter water transmission main projects – include cathodic protection (CP) test stations in the designs to allow field crews to collect data. There is no regular program of data collection within the utility for the information from these CP test station sites.

Because there are currently built-in redundancies in the pump stations, pumps are run to failure; however, plans exist to use SCADA upgrades to trend motor data and predict when pumps may fail. Transferring such SCADA data into Maximo and the utility's geodatabase will also further enable condition assessment tracking for water and sewer system facilities.

Inventory Management

The utility maintains separate inventories of spare parts and equipment to support its asset management activities for each of its separate facilities. Each treatment plant has its own storage room for parts and material, and it is maintained and kept stocked by the plant crew. The Operations and Maintenance Division has a shop to work on equipment and a warehouse to store parts and materials for the distribution and collection systems. No centralized system for all facilities is used to track spare parts availability on a utility-wide basis. Spare parts and equipment are generally available from stock. Currently, critical stock items are not defined or maintained at any of the facilities. While it has the ability to track inventories, Maximo is not currently being used for this purpose.

IT Solutions

AWWU currently uses several different systems for specific asset management functions. Data for these systems are stored in one production database.

Maximo is used as a computer maintenance management system for the collection and distribution systems as well as for all treatment facilities in the utility. Preventive and reactive work orders are recorded in this system, creating asset histories. These asset histories and reports created in Maximo are linked to the utility's geodatabase to allow access to the history of some infrastructure, typically pipelines. The utility plans to rework this to improve the link. Maintenance reports and asset histories are available for review and analysis through Maximo.

For the water distribution and wastewater collection assets (including pumping stations), AWWU developed a complete network inventory of its water distribution and wastewater collection assets in ArcGIS. The utility used this inventory to build a hydraulic computer model of its water and wastewater systems using InfoWater and InfoSewer software from MWHSoft. Each model includes the comprehensive systems of Anchorage Bowl, Eagle River and the Northern Communities, and Girdwood. Additional information was incorporated into the models using historic production and flow records, metering records, billing records, historic SCADA system trends, as-built drawings, and institutional knowledge from AWWU staff. These models were developed over the last 3 years, and are currently being used to model flow, pressure, usage patterns, facility operation, fire flow, water hammer, and water age in each system. These models were recently completed and used to run scenarios for system modifications. These models are used to assist in planning, design, maintenance and operations. There are plans to feed these models with SCADA operational data in the future.

Plan Set is a separate system; this electronic database was built by the utility to track changes to record drawings resulting from recent projects. The complete set of record drawings for the utility is stored and maintained for use in future projects, routine maintenance, planning, or emergencies.

The city-wide PeopleSoft financial and human resources applications are used by utility financial and human resources staff to support financial/cost, project, and personnel management. Given the way that the city-wide PeopleSoft system has been configured, the asset management capabilities within PeopleSoft are currently inadequate to meet the legal and regulatory requirements of a modern water/wastewater utility like the AWWU. For instance, the inability to track historical capital improvement project costs has hampered generation of future cost/value trends for utility assets. Also, the lack of good asset data synchronization between PeopleSoft, GIS, and Maximo has stalled efforts to drive full asset life-cycle management within the utility. As part of its 2005 IT Master Plan, AWWU has identified future projects for implementing a new configuration of PeopleSoft (or another Tier-One ERP system) for its own financial and asset management as well as for establishing master data management among critical information systems with regard to assets.

Customer care and billing is provided by Indus' Advantage CIS system; the utility uses an electronic time collection system which is tied to Maximo and to the financial system.

Rehabilitation and Replacement Planning

AWWU uses a fairly centralized approach to planning for asset rehabilitation and replacement. AWWU has a strong planning component, and uses planning to guide design and maintenance. Projects are developed and prioritized in the master planning process.

Water and sewer master plans are developed every 5 to 7 years and have a 20-year planning horizon. These master plans cover distribution and collection systems; in the process of completing a master plan, a capital improvement project list (CIP) is developed. This CIP is then passed on to the Engineering Division for implementation. Although the projects therein are described as capital projects, many (up to 90% of sewer projects) are actually a form of system repairs or rehabilitation, designed to sustain existing infrastructure such as major CCTV work and condition analysis of pipelines.

AWWU has also initiated studies of its inflow and infiltration (I&I) through the use of flow monitors, and of corrosion through the use of cathodic protection test stations for certain strategic pipelines as a part of the master planning process. These studies have assessed the condition of underground assets and identified and prioritized projects for rehabilitation, replacement, and performance improvement. These projects are included in CIP lists developed in the master planning exercises. The I&I data has been used to determine capacity remaining in key pipelines in the Anchorage area, as well as to identify locations for rehabilitation to trim peaks off the maximum flows seen in the Girdwood WWTP. The master planning process also provides an overview of upcoming regulatory issues that might prove operationally challenging to meet.

Each treatment facility goes through a similar process of facility planning, which outlines upgrades and modifications to improve operations or meet capacity issues every 5 to 7 years.

Valuation and Depreciation

As CIP projects are completed, and the constructed facilities are commissioned, the utility's financial management personnel record these facilities as new fixed assets in the City's PeopleSoft application. Using the PeopleSoft application, these fixed assets are depreciated per GAAP (Generally Accepted Accounting Principles) and GASB (Government Accounting Standards Board) guidelines. As such, the depreciation is on a straight-line basis rather than on the basis of asset condition assessments, which makes the depreciation irrelevant to infrastructure asset retirement decisions. AWWU depreciates assets on a straight-line basis using asset classes. The life of each asset class is monitored and revised to ensure that the asset life of each asset class accurately reflects the asset class' depreciable life.

IV. COSTS, SAVINGS, AND IMPROVEMENTS TO DATE

Most of the improvements are relatively recent, and there is not a performance reporting system in place to track the changes seen in operational costs to date as a direct result of preventive maintenance activities or operationally based infrastructure improvement projects. AWWU CIP lists are developed with lower operational costs in mind. Sewer lines with intense cleaning requirements are reviewed to determine if a capital project will reduce the costs associated with the labor involved in cleaning and maintaining the older line. Additional water lines have been installed to eliminate pumping to certain areas served by the utility. A program of SCADA system development has been ongoing to replace legacy systems to reduce operating costs of the SCADA system, facilitate remote operation of facilities to increase efficiencies of operation, and reduce certain plant operating costs (e.g., reduce energy use for major equipment items). Projects like these are analyzed and modeled in the master plan process and a cost-to-benefit analysis is done on a project-by-project basis once in the CIP.

Smaller scale projects are also being implemented such as pump upgrades to reduce maintenance and operations costs, and routine CCTV work on lines that are cleaned to develop information on conditions.

V. LESSONS LEARNED

The utility has recognized several major lessons that can drive future success in overall asset management. When making a purchase of asset management technology, ensure that a needs analysis is done and that the purchased product is the technology that most accurately meets the application's needs. Also, when new information technology solutions are implemented to support asset management or operations, it is important to change the business practices of the utility to meet the application, rather than customizing the application to match current practices. Finally, high quality upfront data and planning should be completed before embarking on any capital project of magnitude. This will ensure that high quality data is utilized to make critical decisions down the road (such as infrastructure retirement decisions).

VI. FUTURE PLANNED ASSET MANAGEMENT ACTIVITIES

Future planned activities to improve AWWU's asset management include the following:

- Continue the planning process improvements already initiated. Implement life-cycle costing and triple bottom line analysis in asset planning.
- Improve planned maintenance activities by establishing and recording the priority and criticality of assets in Maximo.
- Develop business intelligence systems to improve utility performance measurement and refine key performance indicators (KPIs).
- Establish the practices and technical mechanisms for improving the synchronization of data between GIS and other applications, and automating the transfer of asset attribute data between GIS and the dependent applications, including the hydraulic models and the CCTV software. Increase access to data in multiple systems by making reports more widely available for decision-intensive business processes associated with asset management.

- Upgrade Maximo and deploy more mobile Maximo applications, which will enable improvements in operation and condition data capture and support expansion of preventive maintenance initiatives.
- Use SCADA upgrades to trend motor data for predicting pump failure.
- Complete comprehensive review of utility asset lives to verify plant depreciation schedules currently in use.
- Conduct condition assessment evaluation of critical water infrastructure (major water transmission mains) for capital planning.
- Update and refine asset records of horizontal plant (water and sewer mains) to increase mapping accuracy through global positioning system (GPS) technology.
- Review and assess customer service level needs to increase alignment of capital planning with desired service levels.

ASSET MANAGEMENT CASE STUDY
CHARLESTON WATER SYSTEM

I. UTILITY PROFILE

The Charleston Water System (CWS) treats and distributes water to Charleston and the surrounding areas and communities in coastal South Carolina. CWS treats the majority of its water at its Hanahan Plant, the largest water treatment facility in South Carolina. The primary water source is the Edisto River. CWS provides water to approximately 400,000 customers with approximately 100,000 service connections. Average flows are approximately 50 million gallons per day (MGD). CWS' peak flows are 70 MGD and total rated treatment capacity is 118 MGD. CWS also provides wastewater services to approximately 94,000 customers with average, peak, and wastewater capacity of approximately 24, 33, and 36 MGD respectively. CWS has 440 full-time employees.

Mr. Kanwal Oberoi heads the CWS Water Distribution Department and can be reached at 1256 Supply Street Charleston, South Carolina 29405, by phone at (843) 727- 6800 or by e-mail at oberoijk@charlestoncpw.com.

The designated "Asset Manager" is Mr. Kevin Whitsett who can be reached at the same address or by phone at (843) 308-8261 or e-mail at whitesettkm@charlestoncpw.com.

II. DEFINED ASSET MANAGEMENT PROGRAM GOALS

The goal for CWS is to continue to implement and improve its asset management strategies and to ultimately combine each individual component into a single, integrated system, accessible by all employees.

III. HISTORY AND STATUS OF ASSET MANAGEMENT PROGRAM

Asset Inventory and Hierarchies

Condition-based asset planning is part of the recurring preventive maintenance (PM) program for asset condition assessments including valve exercising, hydrants inspections, etc. Planning for emergencies includes set-asides from both recurring O&M and CIP contingency. Regulatory planning is part of the budget process and includes ISO 14000 criteria to take aspect views of how projects affect the environment. The utility complies with USEPA Region IV requirements and has received two USEPA excellence awards.

CWS' standards and specifications committee determines material requirements. A limited list of approved products is documented as well as a method to review new products. All new products must be pre-approved by the committee and the utility maintains a limited number of preferred items such as hydrants, valves, etc. The utility uses a "smart" numbering system for valves and hydrants. All other assets are auto-numbered by CityWorks (CMMS system published by Azteca) when entered into the database.

Occasionally, some "no-cost-to-inventory" items are provided by developers. New contractor developments must be produced against utility specifications. Developers pay for all upsizing of capacity. When assuming utility service responsibility for older communities, the utility first conducts a condition assessment of existing assets, then assesses a fee prior to acquisition to pay for out-year R&R.

Condition Assessment

Using a two-to-three year cycle of unidirectional flushing of the entire system, CWS incorporates condition of assets into flushing procedures and codes on a 12-point system that includes such items as age, breaks, soil, cost, and politics. Any one of the points can over-ride the others if critical. Condition criticality then establishes alarms for concentrated activity on identified assets. This information is included in both CMMS applications and in the GIS and becomes part of the preventive maintenance schedule. Direct connectivity of condition assessment data to the CMMS for asset history tracking has not yet been established but is planned for this year.

Risk Criticality Assessment

The 12-point condition assessment described above includes factors for risk and criticality.

Maintenance Management (preventive, predictive, reliability centered)

Operations and Maintenance are activities integrated within the utility. Operators perform some major inspection and PMs. Operations are capacity, management, operations, and maintenance (CMOM) compliant using highly stringent USEPA Region IV wastewater collection criteria.

Service requests from the Customer Information System (CIS) for meters are automatically created and integrated with CityWorks. Work order procedures for other customer requests remain a partially manual process, using direct dispatch and manually produced white cards. Plans are in effect to fully integrate the CIS and CMMS soon. CWS also plans for all field crews to have laptops soon, with wireless connection to CityWorks.

Work order planning is accomplished by maintenance supervisors for water distribution and processing plants. Wastewater distribution has planners assigned.

The PM program is based primarily on the 12-point system which triggers PM “alarms” and flags are sent to managers.

Purchasing and Inventory Management

Currently, the warehouse system resides on both the mainframe and CityWorks. Stock levels are audited weekly including “rolling stockrooms to maintain synchronicity.” Replacement items or parts are kept in-house for all items. Items in the field that cannot be repaired due to “parts no longer available” are replaced.

Use of IT Solutions (tools and system integration)

CWS uses CityWorks (updated in 2006) for buried infrastructure and Datastream MP2 for plants and shops. CityWorks allows direct integration with GIS, inventory, and accounting as well as allowing CWS to achieve GASB 34 requirements. One drawback is the lack of compatibility with the aging mainframe server system still in use in the main office. CWS is currently developing improved means, through CityWorks, to track and eventually “roll-up” costs, although that capability has not yet been implemented. CityWorks is automatically integrated with ESRI's GIS through use of a shared database. Both locations and features are enabled within the system.

Capital and Renewal and Replacement Planning, Valuation and Depreciation Methodology, Life-Cycle Costing Model

CWS Capital Improvement Program (CIP) is the center of its asset management program. The CIP projects requirements 5, 10, and 15 years out and budgets for 5 years out. Demand projections are created for growth and replacement, using condition assessment criteria to determine project priorities. Computer hydraulic models focus attention on candidate assets, with break and repair histories used to prioritize projects. The utility uses criteria from the AwwaRF's Rehabilitation and Replacement study (Deb, Grablutz, Hasit, Snyder, Loganathan and Agbenowski 2002) as its model. CIP projects come from two directions: new requirements and current problems. The utility has about $2M set aside each year, some from Bonds, some from "recurring" O&M surplus, for R&R projects.

The O&M expense budget is supported by revenue. Budget development is a yearly detailed process which is a combination of zero-based budgeting and history. Growth rates are included, using a model developed under a consulting contract. Rates are set by the board, with allowed increases based on CIP and growth.

The utility used straight-line asset depreciation methodology, with plans to move toward the modified method soon, which accounts for maintenance performed to maintain the asset value. Recent upgrades of bond ratings were based on accounting efficacy. Federal grant funding is aggressively pursued by the utility; however, there is not much money available from the state. Private funding is not available. CWS uses ISO 14000 with rotating internal to external asset management program audits every 6 months.

Cultural and/or Organizational Changes

CWS has an ongoing plan for organizational development. A "retooling committee" projects organizational and staff requirements and meets two to three times per year for review. Changes to the organizational structure are based on the needs of the customers. People and function requirements are based on growth projections.

Asset management goals and objectives are not yet defined in writing although they appear to have been adequately communicated and understood by appropriate utility staff. There is a designated asset manager assigned to the utility.

IV. COSTS, SAVINGS AND IMPROVEMENTS TO DATE

Although managers indicate confidence in the progress of program development, the program is new enough that cost enhancements and saving have not yet been analyzed. However, significant performance improvements are evident throughout the utility and there is obvious enthusiasm to continue program development.

V. LESSON LEARNED

Clear understanding of the utility's asset management goals and objectives is considered vital to program success. Maintenance and asset management reporting is essential, although most reports are generated ad hoc, on demand. It was expressed that the maintenance management software is not currently being effectively utilized and is a subject for management concentration for the coming year.

VI. FUTURE PLANNED ASSET MANAGEMENT ACTIVITIES

Utility managers indicate ongoing plans to enhance CMMS usage, strengthen automated reporting processes, to establish consistent asset hierarchies to allow cost roll-up and assessment, and to begin using asset performance and life-cycle costing as additional tools for CIP decisions.

ASSET MANAGEMENT CASE STUDY:
DISTRICT OF COLUMBIA WATER AND SEWER AUTHORITY

I. UTILITY PROFILE

The District of Columbia Water and Sewer Authority (“DCWASA” or “the Authority”) provides water distribution, wastewater and stormwater collection, and wastewater treatment services to 570,000 residents of the District of Columbia. In addition, the Authority treats wastewater from portions of Prince George’s and Montgomery Counties in Maryland, and portions of Fairfax and Loudoun Counties in Virginia. The District of Columbia collection system is a combined storm and sanitary sewer system. The average wastewater collected and treated is 330 million gallons per day (MGD), with a peak capacity of 1,074 MGD. There are 120,000 retail water and sewer connections. The average water delivered is 130 MGD, with a peak of 180 MGD. The Authority has 1,000 employees.

The Authority’s contact person for this project is Mr. Charles W. Kiely, Assistant General Manager. Mr. Kiely’s telephone number is 202-612-3590 and his e-mail address is charles.kiely@dcwasa.com.

II. DEFINED ASSET MANAGEMENT PROGRAM GOALS

Authority management considers itself to be new to asset management although they have significantly increased activities during the past year. The Authority’s asset management goals are not formally defined in writing, but management believes the goals presented below are adequately communicated and understood by the appropriate staff. Senior managers are in charge of various components of the Authority’s asset management program.

Management recognizes that using a computerized maintenance management system (CMMS) is not, by itself, an asset management program. The CMMS is viewed as a tool that supports the Authority’s asset management program.

Since 1996 when the Authority was established, it has invested in a major ($1 billion) reconstruction program at the wastewater treatment plant. This level of investment was necessitated by a federal Environmental Protection Agency (USEPA) consent decree. DCWASA’s asset management program goal for this plant is to maintain the operational performance of the new and rehabilitated assets.

The authority has established preventive maintenance (PM) programs for both plant and underground infrastructure. Management wishes to leverage PM programs to gather additional condition and cost data to support predictive and replacement analyses. Additional program objectives include: improve spare parts management, justify staff resources (more or fewer), improve work quality, and implement other asset management best practices.

III. HISTORY AND STATUS OF ASSET MANAGEMENT PROGRAM

Asset Inventory and Hierarchies

The wastewater treatment plant’s primary pieces of equipment are identified in a Maximo CMMS by a unique location. Plant equipment is not identified independently of its location. The list of plant assets is approximately 80% complete. For the distribution and collection systems, unique asset IDs have been established for valves, hydrants, meters, reservoirs, mechanical equipment, catch basins, and most manholes. However, water and sewer mains do not have unique asset IDs.

Condition Assessment

When the Authority was created in 1996, the condition of the plant assets was reviewed. This resulted in a $1 billion capital improvement program for asset rehabilitation, replacement, and reconstruction. Because of this capital program, most of the plant equipment is less than 10 years old. Plant management is concerned that, while preventive maintenance is performed, much of the observed condition data is not collected or documented in the course of conducting those preventive maintenance activities. Management desires to collect condition data to support predictive and reliability centered maintenance. Alternatives considered to address this issue include:

- Developing checklists for use during preventive maintenance activities;
- Training staff to observe conditions and report them;
- Improving business processes;
- Providing staff with history data from prior preventive maintenance activities, inspections, and corrective work orders; and
- Deploying simplified field data entry.

Condition information regarding the collection system is entered into Maximo (e.g., CCTV inspection data, results of preventive maintenance activities including corrective work orders, etc.). For the water distribution system, condition data is obtained when preventive maintenance is performed, including valve cycle operations and hydrant flushing. The main break history, captured by premise addresses, is viewed as an indicator of water main conditions.

IT Solutions

The Authority implemented Maximo at the wastewater plant in 2003. This system replaced an older CMMS at the plant. In 2006, Maximo was extended to manage maintenance in the distribution and collection systems.

The Authority is currently integrating Maximo and the District of Columbia government's OCTO GIS base map. Distribution and collection assets are being entered into GIS. Graphic outputs are available for Hydrants Out of Service and Work Order History. Additionally, in the past 5 years, the Authority has implemented a new Customer Information System, an Automated Meter Reading (AMR) system, and a Lawson financial system (used for parts purchasing and receiving). The financial system is not integrated with Maximo.

Maintenance reports and asset histories are available for review and analysis. The Authority can cross-reference asset history data by a variety of parameters for analysis. Reports from the automated system can be provided for work planning, preventive maintenance, and work order costs.

Maintenance Management – Plant and Pump Stations

The Authority performs both preventive and predictive maintenance at the levels that management feels is appropriate (25% reactive work orders). When new equipment is installed, manufacturers' recommended preventive maintenance schedules are entered in Maximo. For legacy equipment, preventive maintenance schedules were carried over from the previous CMMS. Time-based PM work orders are generated by the CMMS for plant process equipment as well as for water and sewer pumping stations. Labor hours (but not material costs) are associated with each completed work order, creating asset histories. PM work orders are generally completed on schedule and completion rates are reported monthly. Estimated hours and work plans have been established for preventive jobs and management is implementing business processes to capture actual hours and report performance against the estimates. These business process improvements are also intended to improve accountability for labor time.

Predictive maintenance activities include vibration analysis and oil analysis on certain mechanical equipment. The high voltage shop has the capability to perform infrared scans, which are used on switch gear and motor control centers. The Authority wishes to improve its predictive maintenance techniques and its analysis of root causes of failures. Personnel turnover has limited the ability of the Equipment Reliability group to perform its mission of predictive analyses, with emphasis on critical equipment.

Maintenance Management – Water Distribution

For the water distribution system, the Authority's preventive maintenance includes valve cycle operations, hydrant flushing and exercising, and PMs on other mechanical assets. The Authority has also dedicated one crew to perform a unidirectional flushing program. Preventive maintenance work orders are generated from Maximo. Corrective work orders are assigned a priority on a five-level scale. When crews perform corrective and construction work, they also perform upcoming preventive and lower priority corrective work in the same block. Inventory data on 39,000 valves was compiled from valve drawings, and critical valves have been identified. Data on nearly 9,000 hydrants has been compiled with assistance from the fire department. A history of main breaks has been compiled from water main work orders, which include a premise address.

Maintenance Management – Wastewater and Stormwater Collection

Maximo was implemented for the collection system in mid 2006. Inspections and preventive maintenance work orders are now generated from Maximo. The Authority's consent decree requires that accurate collection system maintenance records be kept. The Authority performs annual cleaning and inspection of its 24,000 catch basins and believes these are generally in good condition. Manholes are not as well maintained. Television inspections are performed on the sewer mains, and the results are entered into Maximo along with corrective work orders that are identified.

Risk and Criticality

The Authority has identified critical assets in its distribution and collection systems. The critical distribution assets are the basis for the Authority's unidirectional flushing program. Critical plant assets have been identified but related information has not been entered into Maximo.

Inventory Management

For the wastewater plant, the Maximo inventory control functionality is not used to control spare parts, identify parts needing to be reordered, or charge parts to work orders. Specific desired improvements include controlling the spare parts inventory in Maximo, linking parts to the equipment on which they are used, creating reorder points, recording parts usage on work orders, and associating parts costs with work orders and assets. For the distribution and collection system, parts usage is noted on work orders but no cost information is included. A standard parts inventory has been established for repair trucks, and parts are charged to trucks when the parts leave the warehouse. There is no separate definition and maintenance of critical stock items.

Purchasing is managed in the Lawson financial system, which is not integrated with Maximo. Considerable parts and tools are purchased from vendors for specific work orders when spare parts and equipment are not available from stock. As a result of both of these factors, parts cost is usually not known to the individuals entering work order completion data.

Rehabilitation and Replacement Planning

Because a complete rebuilding of the Authority's plant is in process, the Authority has not developed a strategic plan for Replacement and Rehabilitation. Authority management believes that it is spending the appropriate amount of money on Replacement and Rehabilitation to maintain the necessary level of reliability and customer service. Specific Replacement and Rehabilitation projects are identified by the Authority's engineers and engineering consultants, who review maintenance records, talk with staff, and conduct inspections of the equipment.

Valuation and Depreciation

The Authority tracks the value of its assets including installed value, book value, and replacement value. The Modified Approach to complying with GASB 34 is utilized. The selection of capital improvement projects utilizes inspections, condition reports, and labor usage data rather than life-cycle cost analysis. Critical asset performance is not routinely analyzed. Root cause failure analyses and failure modes and effect analyses are not performed.

IV. COSTS, SAVINGS, AND IMPROVEMENTS TO DATE

Prior to the $1 billion reconstruction program that began in 1996, the Authority's annual wastewater treatment plant maintenance budget was approximately $34 million. The plant maintenance budget in 2006 was $21 million. This budget considers that nearly all of the equipment is less than 10 years old and that the PM programs are expected to maintain the operational performance of the new and rehabilitated assets.

Management believes that the water distribution system's asset management program is relatively mature, including the following components:

- Main break histories
- Valve cycle operations
- Hydrant flushing
- Water quality history data

- Identification of critical assets
- Unidirectional flushing program
- Replacement of lead services
- Cross connection control
- Replacement of 40% of hydrants in the next few years
- Dead end main elimination

As a result of the flushing and valve cycle operations programs, fewer valves need replacement because they are being operated more. Since the valve cycle operations program was established, the Authority has been able to reduce PM frequency from every 12 months to every 18 to 24 months.

The Authority's recently-installed fixed network Automated Meter Reading (AMR) system enables customers' potential water leaks to be detected. This functionality is being used by DCWASA to notify customers of possible leaks and water wastage as soon as the problems are detected. This has contributed to a 30% reduction in the call volume for metering issues.

V. LESSONS LEARNED

Management recognizes that using a computerized maintenance management system (CMMS) is not, by itself, an asset management program. The CMMS is viewed as a tool that supports the asset management program. It is important that the maintenance organization understand the linkage between the CMMS and asset management.

A successful asset management program requires active sponsorship by top management, and complete buy-in from all involved parties. This includes commitment and support for all aspects of the asset management effort.

Based on its experience using Maximo, the Authority has learned the following lessons regarding CMMS deployment:

- More comprehensive training needs to be provided on the software, business processes, and asset management best practices and refresher training.
- More tailored reports and queries need to be developed to provide management with reliable and complete information at the time it is needed.
- Adequate resources, including funding and staffing, need to be available.
- Consulting advice and assistance may be helpful to support the complete implementation of the CMMS.

VI. FUTURE PLANNED ASSET MANAGEMENT ACTIVITIES

Future planned activities to improve DCWASA's overall asset management program include the following:

- Improve asset management business processes to reflect best practices and take maximum advantage of the available technology.
- Improve the work culture to improve quality and address quality assurance.
- Implement electronic document management technology to provide crews with drawings and O&M manuals.

- Train maintenance personnel to provide better feedback from preventive maintenance jobs, including more comments, condition data, and follow-up work orders.

Future planned activities specific to DCWASA's wastewater treatment plant's asset management program include the following:

- Use the CMMS for job costing in support of replacement decisions and staff performance measurement.
- Analyze CMMS data for determining the right size of maintenance staff, as well as optimum crew sizes for various types of work.
- Begin using equipment runtime for scheduling PMs.
- Implement inventory control of maintenance spare parts.

Future planned activities specific to DCWASA's distribution and collection system asset management programs include the following:

- Use the CMMS for job costing in support of replacement decisions and staff performance measurement.
- Analyze CMMS data to determine the appropriate size of maintenance staff, as well as optimum crew sizes for various types of work.
- Develop support for replacement of steel water mains.
- Develop support for planning tunnels and additional storage capacity, plus separating the storm and sanitary sewers, to eliminate flooding and overflows.

ASSET MANAGEMENT CASE STUDY: DUPAGE WATER COMMISSION

I. UTILITY PROFILE

The DuPage Water Commission (Commission) distributes water to Chicago suburbs in DuPage County, located west of downtown Chicago. The Commission purchases its treated water supply from the City of Chicago (City), whose source is Lake Michigan. The Lexington Pumping Station, the largest treated water pump station in the State of Illinois, pumps the water to the Commission for distribution. The Commission provides water to a population of 750,000 residents and delivers an average of 95 million gallons per day (MGD), with a peak flow of 185 MGD. The Commission has wholesale water purchase agreements with many municipalities in DuPage County. The Commission currently employs 33 full-time employees.

The Commission's contact person for this project is Mr. Terry McGhee, Operations Manager for DuPage. He can be reached by e-mail at mcghee@dpwc.org or by phone at (630) 834-0100.

II. DEFINED ASSET MANAGEMENT PROGRAM GOALS

The goal of the Commission is to adopt an asset management discipline to maximize the life of infrastructure assets in order to continue providing quality water at affordable rates. The Commission has a clear plan to achieve this overall goal by identifying and working toward defined interim goals. This includes a maintenance management best practices implementation, integration of systems to improve availability of data, and education of its personnel about current industry trends regarding asset management; as well as specific maintenance practices related to DuPage equipment.

III. HISTORY AND STATUS OF ASSET MANAGEMENT PROGRAM

The Commission has used Datastream MP2 (a computerized maintenance management system, or CMMS) since 1996. This CMMS System is a standalone implementation with no integration and is used primarily as a work order system. Very little data out of the system supports asset management practices. In 2006, the Commission decided to upgrade to Infor's (formerly Datastream) current product, Datastream 7i, to allow for integration with its geographic information system (GIS) and accounting packages, and to achieve the requirements of the Governmental Accounting Standards Board, Statement 34 (GASB-34). The fully integrated end solution is expected to minimize duplicate data entry and allow the Commission to make more informed business decisions with the integrated data. The Commission is using an asset management consulting firm to implement asset best practices and ensure that the system implementation will support these best practices.

The Asset Management Program has now been defined through a series of best practices workshops and is fully supported by the Datastream 7i software configuration and setup. The Commission currently has 10 named users in the Datastream 7i system and will eventually provide access to all personnel. The users include supervisors, key maintenance personnel, and select management and administration personnel. The number of licenses, and the fact that Infor provides only named licenses for the 7i product (opposed to concurrent), has presented some challenges to the first phase of the implementation as indicated in Maintenance Management and Purchasing and Inventory Management sections below.

A phased approach is being utilized and the first phase includes the data migration to Datastream 7i from MP2; implementing work processes to institute best management practices; and implementing the basic software functions of work, inventory, and purchasing modules. Future phases will take full advantage of additional functionality in the 7i system and address integration to other systems such as GIS, modeling decision support tools, and other accounting modules. The guiding principle is to implement a solid maintenance management system that will support the Asset Management Program.

Asset Inventory and Hierarchies

Although the MP2 system did not support implementing a true asset management program, it did contain a fairly complete inventory of assets which the Commission maintains. Some gaps were identified and each Division Supervisor was advised of assets which should be entered and tracked in the new 7i system. The addition of these assets will be an ongoing project following go-live of the 7i system. The GIS system was also reviewed during this process to ensure that any changes made to the asset inventory would be supported in a future integration. The Commission also used the upgrade process as an opportunity to review all data collected for assets, to identify missing and incorrect data, and to create a plan to collect or update data as part of its work management processes.

The MP2 system did not support a hierarchical structure, and the standard data conversion from MP2 to 7i did not account for adding this functionality. During the business process implementation, the Commission defined its asset hierarchies based on cost tracking needs as well as on maintenance management requirements. Because the linking process for asset hierarchies is somewhat tedious in the 7i product, the Commission worked with its consultant to have Datastream perform this work during the conversion through an automated API process.

The equipment hierarchy now in place supports cost reporting to all system and/or division levels, and provides maintenance users the ability to drill down to a specific asset in a visual manner.

Condition Assessment

A condition assessment has not been performed at this point in time. This will be addressed in a future phase and during the integration to GIS and accounting software packages.

Risk/Criticality Assessment

Asset criticality best practices were conveyed during one of the implementation workshops. The Commission has identified its high cost, highly critical assets and will begin assigning criticality to the asset records shortly following go-live.

Maintenance Management (preventive, predictive, reliability centered)

The Commission had already adopted a preventive maintenance (PM) discipline and was at or near the best-in-class metrics across all divisions. Approximately 80% of work performed is of the preventive nature. The PM program was defined by maintenance supervisors and is based on manufacturers' operations and maintenance recommendations. All of the PM activities in the Datastream MP2 program were migrated to the new system. Some gaps were identified, specifically in the areas of skipping PMs and generating PMs at longer-than-acceptable intervals. Improvements to these processes were documented and plans are in place for improvement.

There is very little predictive maintenance (PdM) performed today, but the Commission is committed to moving more toward PdM and Reliability Centered Maintenance (RCM) in future phases. Other asset management practices the Commission wishes to explore and implement in future phases include:

- Root Cause Failure Analysis
- Inspection Management
- Increased Meter-Based PMs
- Calibration Analysis

All of these items are addressed in existing Datastream 7i functionality. The Commission will implement these in a similar fashion to the core components of the software: best practices workshops, current state analysis, future state process definition, and software configuration. The process will then be rolled out during that particular phase go-live.

Reactive maintenance for the Commission is usually emergency related. Main breaks, water shutoff requests, and other reactive activities represent the typical work order that is entered, usually after the work is completed. Reactive maintenance within the facilities is typically not scheduled and often not tracked in MP2. Improved processes addressed these gaps and now all work exceeding 30 minutes in duration is captured on a work order.

Due to the limitation of having 10 named users, many work requests for facilities are generated by e-mails and sent to Division Supervisors. They will then enter the work order into Datastream 7i.

Purchasing and Inventory Management

The Commission had varying degrees of use of the inventory and purchasing modules of MP2. Spare parts were tracked in the system, but stock levels were not kept up to date. There is no process for identifying obsolete parts using MP2, and very few parts lists existed that tied inventory to assets.

Purchasing processes also varied greatly from one division to another. Some personnel filled out paper forms and submitted them for approval, while others used the MP2 purchase order and printed it out for approval. No integration existed between the current CMMS and the Commission's purchasing software package.

The purchasing and inventory process of the Commission's three divisions was reviewed and streamlined. Recommendations were made and accepted to conduct a physical inventory following the go-live of 7i. The inventory will be maintained and most divisions will begin using 7i functionality to identify ideal stock levels and report when re-ordering is suggested for those parts.

A purchase request and approval process was defined and documented that will allow key users (technicians, supervisors) to enter purchase requests that are approved by the General Manager. Due to the current limitation of having 10 named users in the CMMS, several manual steps exist in the current process. Sixty percent of Commission personnel must send purchase requests to named users of the CMMS to have them enter the request. One of the review steps (accounting) requires that a hard copy of the document be submitted to accounting for account number verification.

Use of IT Solutions (tools and system integration)

Currently, no integration exists related to asset management. Asset management data and functions are spread across the CMMS, GIS, and accounting packages. Future integration is planned to streamline processes and minimize duplicate data entry.

Capital and Renewal & Replacement Planning; Valuation and Depreciation Methodology; Life-Cycle Costing Model

Prior to the implementation of the Asset Management Program, very little analysis was performed comparing maintenance management costs to asset depreciation, valuation, or replacement costs. Much of the Commission's infrastructure is new. In many cases, identifying the useful life of equipment is very difficult. The Commission recognizes the need to integrate maintenance cost information with equipment value to aid it in replacement planning, and in making asset maintenance decisions (replacement vs. repair). Much of this will be addressed during a future phase that integrates accounting software with the new CMMS.

Currently, the accounting standard defines an asset as any capital investment of $5,000 or more. The Commission utilizes a straight-line depreciation of its assets. The book value of equipment is not available to CMMS users, including Division Supervisors.

Cultural and/or Organizational Changes

The basis of the Asset Management Program implementation was related to change management and awareness at all levels of the organization. Commission management brought recognized leaders in asset management on-site to convey best practices, to provide an understanding of why it is important, and to explain how to achieve success. The success of this implementation will not be due to the software or a star project performer, but rather the understanding and acceptance of change within the organization driven by asset management requirements.

IV. COSTS, SAVINGS, AND IMPROVEMENTS TO DATE

The Commission has worked with partner consultants to provide the following:

1. **A clear roadmap to an Asset Management Program:** "If you don't know where you are going, how will you know when you get there?"
2. **CMMS Implementation Oversight:** Utilizing seasoned professionals who have led implementations within the water industry on many projects ensures that the wheel will not be re-invented and that typical pitfalls can be avoided.
3. **Best practice business processes:** Proven methodology to convey best in class process, identify current state, and achieve commitment to improve by addressing the gaps in revised business processes.

The Commission has invested approximately $110,000 in CMMS implementation services and Asset Management Program activities to date. The go-live has been postponed due to data conversion issues with the vendor and is tentatively scheduled for January 2007. It is too early to accurately estimate savings and qualify improvements at this point.

V. LESSONS LEARNED

Regarding the CMMS implementation, a data conversion decision was made without identifying and weighing all associated risks at the project planning stage. This delayed the project approximately 2 months.

It was also learned that the software vendor often requires more than a brief overview of the best practices adopted by the utility to assist the vendor in configuring the software. More time and documentation could have been allocated to this task.

Finally, the Accounting Manager should have been integrated into the process at an earlier stage. The process of purchase requests had to be revisited and redesigned following Accounting's additional input. This extra step could have been avoided had the Accounting Manager been included as a key customer/project stakeholder earlier in the process.

VI. FUTURE PLANNED ASSET MANAGEMENT ACTIVITIES

The Commission has a robust plan to move forward with the improvement of the Asset Management Program. The following will be implemented and are listed in the order of highest priority:

- **Integration to GIS** – will improve locating assets and provide the ability to share asset attributes between GIS and CMMS. This will also finalize the CMMS database by including pipelines as equipment.
- **Integration to accounting** – this is critical for GASB34 compliance and to improve the decision making process for repair versus replacement of assets. This will also streamline the purchase request process.
- **Mobile solutions for technicians** – will allow all maintenance technicians and operations personnel to enter and close their own work orders while on the job. This will reduce paper, eliminate lost work orders, and provide real time asset tracking.
- **Increase licenses** – analysis will be done to determine which users need full access and which personnel require only work request and purchase request access to the system. This analysis and resulting requirements will save the Commission money by having the right number of licenses for each role.
- **Various future phases for additional functionality implementation** – this includes, but is not limited to, the following functionality:
  - Root Cause Failure Analysis
  - Inspection Management
  - Increased Meter Based PMs
  - Calibration Analysis
  - Automatic parts reordering
  - Condition Assessment
- **Decision support tool** – linking CMMS and financial information to help with CIP planning activities.

ASSET MANAGEMENT CASE STUDY:
HENRICO COUNTY DEPARTMENT OF PUBLIC UTILITIES

I. UTILITY PROFILE

The Henrico County Department of Public Utilities (DPU) provides water treatment, water distribution, wastewater collection, and wastewater treatment services to a population of more than 270,000. There are 90,000 water and sewer connections. The average water treated and delivered is 44 MGD, with a peak of 60 MGD. The total treatment capacity is 90 MGD, of which DPU's Water Treatment Facility (WTF) has a capacity of 55 MGD, and the remaining 35 MGD is treated water purchased from the City of Richmond. The average wastewater collected and treated is 49 MGD, with a peak of 125 MGD. The total rated treatment capacity is 75 MGD. The utility staff totals 316 FTEs.

The utility's contact person for this project is Mr. Arthur D. Petrini, DPU Director, whose e-mail address is pet12@co.henrico.va.us. Mr. Petrini's telephone number is 804-501-4280.

II. DEFINED ASSET MANAGEMENT PROGRAM GOALS

The utility's asset management vision was defined in 2003 as follows:

> *"The Henrico County Department of Public Utilities will deploy an integrated, state-of-the-art system to align business processes with Best Practices in Enterprise Asset Management."*

Each element (i.e., phrase) in the vision statement implies specific objectives for DPU's asset management program. Since this vision's creation, it has provided guidance on asset management matters for DPU's management team. These objectives are reflected in planning for capital improvements, rehabilitation and replacement priorities, resourcing for preventive programs, and daily management decisions.

III. HISTORY AND STATUS OF ASSET MANAGEMENT PROGRAM

Asset Inventory and Hierarchies

The utility developed a networked inventory of its water distribution and wastewater collection assets in 1993, using Hansen Information Technologies as a contractor. Unfortunately, that asset inventory was not kept up to date as assets were subsequently added and retired. A GIS data conversion effort in 2000-2002, followed by data reconciliation and the implementation of business processes for maintaining the asset inventory, has resulted in a credible GIS-based inventory of underground assets.

At the Water Reclamation Facility (WRF), the utility developed an inventory of equipment and facilities in a hierarchical structure, associated with the implementation of a Datastream MP2 computerized maintenance management system (CMMS) in 2001. A new Water Treatment Facility went into production in 2004. The hierarchical inventory of its equipment and facilities was created during construction, and has been entered into a Datastream 7i CMMS.

Each of the three asset inventories has a different asset identification scheme. Within each inventory, each asset has a unique asset identification code. Assets have not been prioritized by criticality in water distribution, wastewater collection, or the WTF. The WRF recently identified critical assets.

Condition Assessment

For the underground wastewater collection assets, television inspection is utilized to record condition data. The utility uses two television inspection vehicles, supplemented by outsourced inspections. A digital system for television inspection data was implemented in 2004, replacing reliance on VHS taped inspection data and improving access to condition information, images, and video. A terabyte server provides permanent storage of images and video. Defect information and location data are coded according to the NASSCO PACP standards, and moved to the Hansen CMMS for use in maintenance scheduling. Plant and pump station equipment condition data is adequately documented and updated as part of preventive maintenance. Water distribution asset condition data is limited to information that can be inferred from exercising valves, flow testing hydrants, and collecting water quality samples.

Maintenance Management

For underground water distribution and wastewater collection assets the utility is increasing its level of preventive maintenance, outsourcing some of this work in its effort to reach the desired levels. A thorough preventive maintenance program is in place for the pumping stations. The preventive maintenance work orders are initiated automatically from the Hansen maintenance management software. Pumping station PM work orders are generally completed on schedule and preventive maintenance completion rates are regularly reported to management.

Both the WTF and WRF plants have developed preventive maintenance programs based on equipment manufacturers' recommendations. The preventive maintenance work orders are initiated automatically from the Datastream maintenance management software. PM work orders are generally completed on schedule at the WTF, and preventive maintenance completion rates are regularly reported to management. The WRF is presently reviewing all preventive maintenance work orders and intervals. The WTF reports that 50% of work orders are reactive, while the WRF reports that 60% of work orders are reactive.

In the area of predictive maintenance, the WTF and WRF utilize oil analysis, vibration analysis, and thermal/infrared sensing (for electrical equipment). The WTF makes an effort to identify the root cause of all equipment failures. The utility does not perform Reliability Centered Maintenance.

Inventory Management

The utility maintains three separate inventories of spare parts and equipment to support its asset management activities. Support for inventory control in all three warehouses is provided by DPU's maintenance management software. However, parts and material are not controlled after leaving the warehouse, even though considerable "truck stock" is carried. Two of the three warehouses have full-time staff. Spare parts and equipment are generally available from stock. There is not presently a separate definition and maintenance of critical stock items.

IT Solutions

For the water distribution and wastewater collection assets (including pumping stations), DPU uses Hansen Information Technologies' IMS Version 7.7. An earlier version of this software was implemented in 1993, and various upgrades have been installed through 2006. Preventive and reactive work orders are recorded in this system, creating asset histories. Labor hours and material costs are associated with each work order. Maintenance reports and asset histories are available for review and analysis. The utility can cross-reference asset history data by a variety of parameters for analysis. Management would like to improve the Hansen CMMS's value by improving reporting, updating the asset inventory, and integrating with service requests in the upcoming county-wide 311 system and GIS.

For both plants, DPU implemented the Datastream 7i system in 2005. At the WRF, this replaced an older Datastream MP2 application. The 2005 implementation project included training in asset management best practices, maintenance process improvements, and creation of dashboards for key performance indicators (KPIs). Preventive and reactive work orders are recorded in this system, creating asset histories. Labor hours and material costs are associated with each work order. Maintenance reports and asset histories are available for review and analysis. The utility can cross-reference asset history data by a variety of parameters for analysis. Management would like to improve this application's value by enhancing its processes for work planning and scheduling, and by improving reporting.

Rehabilitation and Replacement Planning

DPU uses a decentralized approach to planning for asset rehabilitation and replacement. Projects are prioritized by the divisions that are responsible for maintaining the assets. The Design (Engineering) division coordinates these recommendations with DPU's long-range master plan and any additional capacity issues.

DPU has begun to document rules, policies, assumptions, and service level requirements associated with asset rehabilitation and replacement decisions. Data to support an improved decision process is being compiled, including asset installation date and asset criticality. DPU management recognizes that additional asset rehabilitation and replacement dollars are necessary to sustain the desired level of service over the long term.

In the collection system, DPU has also initiated studies of its inflow and infiltration (I&I) and of odor and corrosion. These studies have assessed the condition of underground assets, and identified and prioritized projects for rehabilitation, replacement, and performance improvement. The I&I study evaluated the cost-effectiveness of various approaches for reducing wet weather flows in the wastewater collection system, recommending the most efficient method for achieving the required performance. These recommendations are presently being implemented.

Valuation and Depreciation

DPU tracks the value of its assets, including installed value, book value, and replacement value. The Modified Approach to complying with GASB 34 is utilized. While asset maintenance and cost history is tracked in the Hansen and Datastream CMMSs, this is not integrated with the County's General Ledger for life-cycle cost analysis. Life-cycle cost analysis is not currently a factor in selecting Capital Improvement Projects due to the lack of data and approach. Critical asset performance is not routinely analyzed. Root cause failure analyses and failure modes and effect analyses are usually not performed, and as such, their results are not routinely available for asset engineering design or improvement projects.

IV. COSTS, SAVINGS, AND IMPROVEMENTS TO DATE

Most of the improvements are relatively recent, and there is not a performance reporting system in place to track the changes to date.

V. LESSONS LEARNED

Whenever new systems are implemented, it is necessary to change business processes to achieve the full potential of the new technology. After new systems go into production, it is important to plan for considerable post-implementation support to refine business processes, "fine tune" system configuration decisions, provide refresher training, maintain the standard operating procedures, conduct post-implementation assessments, and implement the recommendations of those assessments.

VI. FUTURE PLANNED ASSET MANAGEMENT ACTIVITIES

Future planned activities to improve DPU's asset management include the following:

- Improve the process for capital improvement program decisions for asset rehabilitation and replacement (R&R). Specific tasks include:

  Documenting R&R planning assumptions and rules for various asset classes.

  Gathering missing asset data that is needed for applying these rules.

  Developing service level metrics for all asset classes.

  Developing long range projections of R&R needs.
- Prioritizing assets by criticality.
- Implementing a "dashboard" presentation of key performance indicators (KPIs) from the Datastream 7i maintenance management system at both WTF and WRF plants.
- Further improve the Datastream 7i implementations by refining associated business processes and configuration decisions, and providing additional training on the software (for users and system administrators), business processes, and asset management best practices.
- Complete the review of all the WRF's preventive maintenance work orders and intervals, and begin a regular, annual update of all WRF, WTF, and pumping station PM work orders.
- Evaluate conversion of an existing position into a "work planner/scheduler" position in one or more of the divisions responsible for asset management.
- Improve the configuration of the Hansen CMMS implementation, along with the associated business processes, management reporting, and usability.
- Implement business processes and systems to continually update the GIS asset repository, and to transfer this asset data to the Hansen CMMS.

- Integrate the Hansen IMS with electronic document management (of as-builts, television inspection images, and O&M manuals), GIS, and DPU's Web-based information portal.
- Provide additional training on the Hansen CMMS software (for users and system administrators), associated business processes, and asset management best practices.
- Improve spare parts inventory management by defining critical stock items, controlling truck stock, and integrating bar code technology into the current tracking methods.

ASSET MANAGEMENT CASE STUDY: LONG BEACH WATER DEPARTMENT

I. UTILITY PROFILE

The Long Beach Water Department (LBWD, or the Department) provides water treatment and distribution services to approximately 460,000 people in and around Long Beach, California. The Department has approximately 90,000 water service connections. The average water delivered is 26 million gallons per day (MGD), with a peak of 60 MGD. The total rated treatment capacity is 62.5 mgd.

The Department also provides wastewater collection services to its customers. The Department has approximately 88,000 wastewater service connections. The difference in number of connections between the water and wastewater systems is due to some properties having multiple water accounts but one wastewater account. Wastewater is conveyed to regional interceptors operated by the Los Angeles County Sanitation District (LACSD) and eventually treated at one of two LACSD wastewater treatment plants (either the Long Beach plant or the Carson plant).

The Department employs approximately 210 full-time equivalents (FTEs). The contact person for this study is Isaac Pai, Director of Engineering. His e-mail address is Isaac_pai@lbwater.org, and his phone number is (562) 570-2336.

II. DEFINED ASSET MANAGEMENT PROGRAM GOALS

LBWD is committed to the long-term maintenance of its infrastructure in a cost-effective manner. Approximately 8 years ago, the Department began a 20-year plan to replace its aging cast iron water mains. The pipes to be replaced were prioritized and grouped into projects. After 8 years of the program, the Department has reduced its annual water main breaks from over 170 per year to approximately 40 per year.

A few of the Department's critical objectives for fiscal year 2005-06 include:

- Continue the cast iron main replacement program by installing 60,000 linear feet of new water main.
- Clean 1.5 million linear feet (approximately 284 miles) of sewer mains. This amount is approximately one-third of the total system of 763 miles of sewer main.

The Department prepares quarterly reports to measure progress against these goals.

III. HISTORY AND STATUS OF ASSET MANAGEMENT PROGRAM

Asset Inventory & Hierarchies

LBWD has implemented a geographic information system (GIS) to help manage its distributed assets. The GIS uses ArcGIS software from ESRI. The GIS representation of the water system is considered to be complete and serves as an asset inventory for pipelines. The GIS also includes an inventory of the reservoirs, pump stations, and valves in the Department's system. Pump stations are represented as nodes in the GIS database; individual components such as pumps are not identified separately. Each asset is assigned a unique identification number.

Condition Assessment

The Department manages a number of programs to evaluate the condition of its assets.

- A valve exercising and replacement program for valves in the distribution system.
- A recurring inspection and coating program for the steel water storage reservoirs.
- A replacement program for water meters, including a more aggressive pace for larger meters.
- A rehabilitation program for water and wastewater pumping stations to ensure reliability, code, and safety compliance.
- A refurbishment program of the water wells that ensures adequate supply of approximately half of the Department's total water supply.
- A proactive preventive O&M program to closed-circuit television (CCTV) inspect gravity sewer pipelines.
- A GIS database for water main breaks that is used to collect, process, and analyze pipe replacement projects.

This condition assessment information is maintained in various electronic databases that can be linked to the GIS.

Maintenance Management

The Department's water treatment plant was constructed in 1997 and has a rated capacity of 62.5 MGD. During the summer, the plant typically operates at between 50 and 55 MGD. During the winter, the Department relies on imported water for much of its supply, and the plant operates as low as 6 MGD. Much of the maintenance work is performed in the winter when treatment trains can be taken off-line. Plant operators inspect water well equipment weekly for the water supply wells that deliver local groundwater to the Department's water treatment plant. These inspections follow a standard checklist developed by Department staff.

Within the past year the Department has implemented a computerized maintenance management system (CMMS) for the equipment at its water treatment plant. The CMMS uses ExpressMaintenance software from Express Technology. The CMMS is being populated with equipment data by Department staff when time permits. Work orders for maintenance on the plant site are issued from the CMMS, and the CMMS is used to track work hours and material costs for completed work orders. The Department intends to eventually use the CMMS to track maintenance performed on mechanical equipment around the distribution system, as well as on the water treatment plant site.

For assets in the distribution and collection systems, separate databases are used to record when maintenance, cleaning, or upgrades are performed. An LBWD supervisor creates work orders for maintenance or cleaning using these databases. These databases can then be linked to the GIS for mapping and analysis. Water main breaks are mapped in GIS and used to identify areas for additional inspection and possible rehabilitation or replacement of assets.

Inventory Management

The Department has a warehouse with common items such as pipes, meters, and fittings. The Department has a wide variety of pumps, motors, and mechanical equipment in its distribution and collection systems. The Department has determined that for most parts, it would not be efficient to maintain spare parts for all the types of equipment that could require attention. Instead, the Department has established relationships with manufacturers and suppliers who can provide replacement parts quickly when needed. Critical parts are not identified or stocked separately.

IT Solutions

The Department uses GIS extensively to manage its assets. Many databases with asset information can be linked with the GIS using unique asset identification numbers. The analysis is then performed within the GIS.

A WonderWare Supervisory Control and Data Acquisition (SCADA) system collects information from around the distribution system and conveys it to the operations building at the water treatment plant.

LBWD uses an H2ONet hydraulic model of its distribution system to help identify needed improvements.

Rehabilitation and Replacement Planning

The Department completed a cast iron water main replacement study approximately 8 years ago. This study provided the foundation for the planned replacement of water mains. The Department spends approximately $6-8 million annually to replace cast iron water mains. Each year engineering and operations staff work together to evaluate priorities and identify final projects as necessary. Planned improvements are identified by hydraulic modeling and GIS cast iron main data.

For the wastewater collection system, the Department plans to update its sewer master plan in 2007. This plan will provide the basis for replacement and rehabilitation planning for the wastewater system.

Valuation and Depreciation

LBWD tracks the value of its assets, including installed value, book value, and replacement value. Assets such as pump stations, reservoirs, and regulating stations have been prioritized according to criticality. LBWD does not use the GASB 34 Modified Approach.

IV. COSTS, SAVINGS, AND IMPROVEMENTS TO DATE

LBWD does not isolate all its costs for the asset management program. The Department has spent approximately $15,000 to implement the CMMS for the water treatment plant.

V. LESSONS LEARNED

LBWD has embraced GIS as the foundation of its asset management program. Separate databases are used to track maintenance activities on the water distribution and wastewater collection systems, but all these databases can be linked to the GIS. GIS has proved to be an effective interface for data retrieval, analysis, and reporting, as well as for generating maps. Some field crews carry mobile computers that allow the crews to access the GIS data while in the field.

VI. FUTURE PLANNED ASSET MANAGEMENT ACTIVITIES

The Department plans to continue to populate the CMMS database with equipment at the water treatment plant. The CMMS will eventually be extended to include equipment in the distribution and collection systems.

The Department expects to focus more attention on its collection system as the result of new waste discharge requirements established by the California Water Resources Control Board. The new waste discharge requirements are intended to reduce sanitary sewer overflows and mandate a number of asset management processes for collection system infrastructure. These required processes include inspection and condition assessment, hydraulic capacity evaluation, and financial planning for rehabilitation and replacement of aging infrastructure. The Department has many of these processes in place, but the waste discharge requirements will require that the programs be formalized and documented.

The Department continues to investigate how to integrate its various information systems, especially its Laboratory Information Management System (LIMS), with other information systems to increase efficiency.

ASSET MANAGEMENT CASE STUDY: LOS ANGELES DEPARTMENT OF WATER AND POWER

I. UTILITY PROFILE

The Los Angeles Department of Water and Power (LADWP, or the Department) provides water treatment and distribution services to approximately 3.98 million people in and around the City of Los Angeles. While LADWP also provides electricity generating and distribution services, this case study only addresses potable water services. LADWP has approximately 705,000 water service connections. The average water delivered is 591 million gallons per day (MGD), with a peak of 765 MGD. The total rated treatment capacity is 1,150 MGD. LADWP's staffing level is currently approximately 1,680 full-time equivalents (FTEs).

The LADWP contact person for this study is Stephan Tucker, Capital Improvement Program Manager. His e-mail address is stephan.tucker@water.ladwp.com and his phone number is 213-367-1228.

II. DEFINED ASSET MANAGEMENT PROGRAM GOALS

LADWP staff has prepared a draft report that describes the Department's asset management program. This report is in draft form (as of December 2006) and has not yet been submitted for approval by the Department's Board of Commissioners. The report outlines the Department's goals for asset management and the associated systems and procedures currently in place. It also shows the projected replacement profile based on the estimated useful life of the various assets. This report will be available for further review after it has been submitted for approval to the Department's Board of Commissioners. After Board approval, the report will be used for communication with Department staff and other stakeholders.

The LADWP Water Services Organization is operating under a 2003 to 2008 Business Plan. This document identifies 10 top priorities for the Department:

- Customer Service
- Productivity
- Environmental Responsibility
- Public Responsibility
- Financial Performance
- Water Quality
- Infrastructure
- Water Supply
- Internal Communication
- Workforce Development

The infrastructure discussion in the business plan includes many of the components of a typical asset management program. The Department's goals under infrastructure are:

- Develop and implement an asset management plan that covers maintenance, replacement, and growth of the water system infrastructure.

- Develop, implement, and communicate a process for prioritizing work and resolving conflicts that is based on financial performance, customer and stakeholder satisfaction, and employee satisfaction.
- Commit resources for maintenance of new facilities as well as for existing infrastructure.
- Operate the system to achieve reliable delivery of water.

III. HISTORY AND STATUS OF ASSET MANAGEMENT PROGRAM

Asset Inventory and Hierarchies

LADWP has implemented a geographic information system (GIS) to help manage its distributed assets. The GIS representation of the water system is considered to be fairly complete and serves as an asset inventory for pipelines. The inventory of mechanical equipment is maintained in the Maximo computerized maintenance management system (CMMS). Maximo also includes the asset inventory for equipment at the water filtration plant. Large trunk pipelines in the Department's transmission system are also inventoried in Maximo but the smaller-diameter pipes in the distribution system are not. Each asset is assigned a unique identification number and a formal hierarchy has been established for assets in Maximo.

Condition Assessment

The Department has performed condition assessment on various components of its distribution system.

- LADWP operates approximately 80 pumping stations. These pumping stations were prioritized by condition and criticality and were scheduled for inspection. Rehabilitation or replacement projects have been scheduled for the 10 highest priority pumping stations.
- LADWP operates approximately 370 pressure regulating stations. In addition to the normal operation and maintenance crews, a dedicated repair and retrofit crew is visiting these regulating stations in order of priority and performing necessary work.
- The LADWP distribution system includes both concrete and steel potable water reservoirs. On average, each reservoir is inspected once every 3 years. LADWP renews the coating on four to six steel reservoirs each year.
- Approximately 70% of the LADWP distribution system is cast iron pipe. LADWP will complete an effort to apply cement linings to all cast iron pipe by June 2007. LADWP has little information on the condition of its pipelines and the factors that affect the remaining useful life of these assets.

Maintenance Management

All maintenance work orders are issued and tracked using the Maximo computerized maintenance management system. The Maximo system is not linked to the GIS system. There is a large backlog of work orders that needs to be completed. Currently, the Department estimates that 20% of the preventive maintenance work orders generated by the Maximo system are completed. LADWP does not track or estimate work hours associated with each work order. Therefore, the Department cannot quantify the backlog of maintenance in person-hours of work. However, the Department recently hired eight additional maintenance staff in an effort to reduce the backlog of maintenance work orders.

When the Maximo system was implemented, codes were established that could be used to track failures. However, there was no consensus among Department staff on a consistent set of failure codes. The failure codes are currently not being used to track causes of failure.

Inventory Management

The Department's spare parts and stores are maintained and provided by a separate division within the Department. Most spare parts are not stored in the Maximo maintenance management software. LADWP has not identified critical parts or established a separate inventory of critical parts. There have been times when maintenance work orders could not be completed because parts were not available. In general, the water system is designed to have sufficient redundancy so that equipment can be taken out of service when necessary for routine or unscheduled maintenance.

IT Solutions

The Department implemented Maximo in 2004 as its computerized maintenance management system (CMMS). The Department currently uses version 5.2 and is planning to upgrade to the newest version of Maximo. Maximo is used to generate preventive and corrective maintenance work orders. A single Water Operations Supervisor is the primary user of Maximo and generates most work orders.

Although the Maximo inventory of existing equipment is complete, the parts inventory and stores inventory are not maintained in Maximo. The Department's spare parts and stores are maintained and provided by a central group within the Department.

LADWP has implemented a geographic information system (GIS) to help manage its distributed assets. The GIS representation of the water system is considered to be fairly complete. Some field crews carry tablet computers that give them access to the GIS while in the field.

LADWP uses hydraulic models of its distribution system to help identify needed improvements. An H2ONet model has been developed for all pipes 16 inches and larger. For more detailed studies, the system has been broken into 102 service zones. Individual models have been completed for about 70 of these service zones using Cybernet software. The individual models are used for detailed review of flow through smaller pipes and facilities.

LADWP maintains a Primavera schedule of its capital improvement projects to help in managing the capital program.

Rehabilitation and Replacement Planning

LADWP has an annual capital improvement project (CIP) budget of approximately $320 million. The Department has identified necessary improvement projects based on condition assessment, hydraulic modeling, and a replacement profile that was calculated using assumed useful life for various assets. Every year the Department evaluates the priorities for scheduled projects and shifts projects as necessary to make the best use of the available capital funds. Approximately two-thirds of capital improvement projects for mechanical equipment are based on corrective maintenance requirements.

Valuation and Depreciation

LADWP tracks the value of its assets, including installed value, book value, and replacement value. Assets such as pump stations, reservoirs, and regulating stations have been prioritized according to criticality. LADWP does not use the GASB 34 Modified Approach. The Department typically does not perform root cause failure analyses.

IV. COSTS, SAVINGS, AND IMPROVEMENTS TO DATE

LADWP does not isolate its costs for the asset management program. The Department's annual budget for operations and maintenance is approximately $290 million for the water system. The annual capital improvement budget for the water system is approximately $320 million.

V. LESSONS LEARNED

The Department is not currently using the full potential of the Maximo system. Material costs are not tracked for work orders, work hours are not tracked or estimated for work orders, and failure codes are not assigned to allow failure cause analysis. Additional resources, training, and business process modifications may be needed to track this information and use it for future planning purposes.

VI. FUTURE PLANNED ASSET MANAGEMENT ACTIVITIES

The Department has prepared a replacement profile showing when its assets should be replaced based on useful life. Major elements such as pumping stations, regulating stations, and reservoirs can be inspected and evaluated. However, the condition information for buried assets such as pipelines is very limited. For the most part, the replacement profile for these pipelines is based on nominal values of useful life for pipelines. The Department is seeking to develop a better understanding of the useful life of these assets and the factors that affect useful life such as pipe material, soil type, traffic loading, and other factors. The Department hopes to be able to develop more accurate estimates of remaining life and more accurate replacement forecasts.

The Department is planning to upgrade to the newest version of Maximo for its maintenance management system. The Department is also evaluating the necessary changes for using the Maximo system to its full potential.

The Department is evaluating its capital project delivery process. In recent years, the execution rate for the capital improvement program is approximately 65%. The Department is evaluating its project management procedures and identifying changes that will enable it to successfully execute its capital improvement program.

The Department is planning to issue a request for proposals to consulting firms for assistance in planning and implementing improvements to its asset management program.

ASSET MANAGEMENT CASE STUDY: LOUISVILLE WATER COMPANY

I. UTILITY PROFILE

The Louisville Water Company (LWC) provides water treatment and distribution to a population of approximately 810,000 in the metropolitan area of Louisville, Kentucky, including parts of Oldham and Bullitt Counties.

There are approximately 450 employees of LWC organized into five major departments as follows:

- Engineering – encompassing engineering, planning, and construction
- Operations – encompassing production/water quality, distribution/operations and customer service
- Finance – encompassing finance, information technology, and risk management
- Human Resources/Training
- Legal Counsel

There are 271,900 water connections. Water is drawn from the Ohio River at three points and treated in two treatment plants. The average treated water volume is 130 MGD with a peak treated volume of 205 MGD. The total rated capacity of the treatment plant is 240 MGD. LWC maintains approximately 3,600 miles of water mains. In addition to serving retail customers, LWC wholesales water to several nearby communities.

The contact person for this project is Bret D. Russell, PE, planning engineer, whose e-mail address is brussell@lwcky.com. Mr. Russell's telephone number is (502) 569-3600, extension 2261. Other key decision makers with respect to asset management include:

- Greg Heitzman, Senior VP, Operations
- Jim Brammell, VP, Chief Engineer
- Jim Smith, Infrastructure Planning/Business Development

II. DEFINED ASSET MANAGEMENT PROGRAM GOALS

Though LWC has not had specifically stated asset management goals, a reorganization of the Planning Department in 2006 states that asset management will be considered when developing budget proposals and justifications. LWC's Strategic Mission includes the following guiding statements:

- **VISION**: To be a water supplier of choice throughout the region, operating in a highly competitive, customer-focused manner; delivering outstanding quality, customer satisfaction and value.
- **MISSION**: To serve the water needs of our customers through outstanding quality, service and value at a market return to our shareholders.
- **VALUES:** Customer Focus, Teamwork, Pride in Workmanship, Trust, Empowerment, Diversity, Continuous Learning, Continuous Improvement

III. HISTORY AND STATUS OF ASSET MANAGEMENT PROGRAM

A review of LWC's programs indicates a broad level of intuitive asset management features currently in place and plans for expansion and consolidation of those features into a more comprehensive asset management program in the near future. Described below are aspects of current practices that comprise LWC's asset management activities.

Main Replacement and Rehabilitation Program

LWC established a Main Replacement and Rehabilitation Program (MRRP) after a 1992 study prepared by CH2M Hill. In the report from this study, main break modeling was provided along with financial strategies and recommendations for a 15-year infrastructure renewal and rehabilitation program. The stated purpose of the annual MRRP has been to replace 500 miles of aging unlined cast iron water main installed prior to 1937. Pipe installed from 1862 to 1865 and from 1926 to 1931 is unlined cast iron pipe and is targeted for removal from the system because of its high failure frequencies in excess of system-wide averages. This vintage pipe also exhibits characteristics that contribute to poor water quality and a reduction in hydraulic capacity, pressure, and flow. Pipelines installed from 1866 to 1925 have proven to be very reliable and had been the focus of the rehabilitation portion of the program with approximately 80% of those water mains targeted for rehabilitation and the remaining 20% for replacement.

MRRP Selection Methodology

A Pipe Evaluation Model was created in 1993 and the criteria listed below were used to help evaluate and justify projects.

Category	Criteria
Geographical	Central Business District, Redevelopment Areas, and Roadway Classifications.
Hydraulic	Small diameter and undersized water mains, and fire flow availability, hydraulic C-factor.
Maintenance	Main breaks, joint leaks, material samples, corrosive soil, installation date, pipe/joint type, and high maintenance record.
Quality of Service	Taste, odor and discolored water complaints, water quality analysis, dead-ended water mains, paving age.

Currently LWC uses a criterion of two breaks per mile per year as justification for replacement.

An extensive cleaning/lining program was conducted for 15 years ending in 2004. Sound, unlined pipe was included and decisions were based on the MRRP program.

Point Capital Program

The Point Capital Program, currently separate from the MRRP planning, conducts renewal of fire hydrants, large meters, services, blow-offs, valves and short sections of distribution and transmission mains. This program is based on the efficient utilization of maintenance crews, and a challenge for the future is to better incorporate the appurtenances into a broader planning context.

Fire Hydrants

LWC has assembled a Natural Work Team Unit focused solely on fire hydrants. All maintenance and point renewal activities are directed through this team. This team and the company work toward specific service level goals including hydrant availability (in service, downtime, etc.), maintenance schedules, flow rate, and density.

Condition Assessment

The condition of aboveground facilities is informally assessed on an ongoing basis and needs are addressed as capital improvement projects. Leak surveys are conducted on the distribution system approximately every 5 years and for the transmission system approximately each year. Otherwise, there is no formal condition assessment program.

Break Data Collection

LWC has been collecting main break data for many years and has an impressive data bank of valuable information. Work crews responding to breaks continue to collect data at the site. There has been a practice of providing training to the crews with respect to data to be collected.

GIS Platform

LWC has constructed a robust GIS platform that includes information on the entire distribution system. This has proved to be a valuable analysis and planning tool.

Utility Coordination Committee

LWC emphasizes utility coordination for all MRRP projects, especially with paving programs undertaken by the Louisville area metropolitan government and the Kentucky Transportation Cabinet. LWC is an active participant in the Utility Coordination Committee (UCC), whose members are represent utilities and public works agencies in Jefferson County. Anticipated construction schedules for all MRRP projects are forwarded to these utilities and public agencies to allow coordination of local infrastructure construction.

Lead Renewal Program

LWC continues to systematically remove lead services from the distribution system to reduce the potential for lead exposure and because of increasing awareness of public health issues and future regulatory compliance. The Lead Service Renewal Program aims to remove 20,000 lead services from the distribution system by 2015. This effort is being conducted by LWC crews and contractors, with an emphasis on coordination with local paving and construction programs.

Meter Change Program

LWC's Metering Group pursues the replacement of meters on the basis of age and type of meter. Meter replacement decisions are made separately from other capital planning efforts.

Work Order System

At the treatment plants, a work order system (MP2) is in place and is approximately 20 years old. An in-house WorkOrder system has also been in place for 20 years for the transmission, distribution, and metering processes. These systems will be replaced with a computerized maintenance management system (CMMS) sometime around 2009. Assets at the plants and pumping stations have unique asset identification codes. The MP2 system tracks labor hours for each work order, but associated material costs may not be consistently recorded to each work order. It is estimated that approximately 75% of the dollar volume of maintenance is reactive as opposed to preventive or predictive.

The company is investigating the purchase of preventive maintenance software to enhance the capability of scheduling preventive maintenance for aboveground assets.

For work in the distribution system, work crews currently arrive at work order locations without asset data, only a work ticket. It is intended that in the future, work crews will have access to asset data at the work site.

Risk Management

LWC has developed a program of non-traditional risk management based on considering events or factors that could keep the company from achieving the major objectives outlined in its Strategic Plan. LWC identifies triggers to such events and analyzes the probability, time to develop, and consequences. This analysis guides other planning and business decisions.

Overall, assets have not been prioritized based on cost or process criticality, although such an analysis was conducted for the major transmission mains.

Financial Management

For several years LWC included an extra 1% in the rates to create a cash basis renewal fund, allowing the replacement of 1 to 1.5% of the distribution system per year that was rate funded rather than debt funded. When a main is cleaned and lined, the useful life is extended 40 years and the rehabilitation cost plus the remaining book value becomes the new book value.

IV. COSTS, SAVINGS, AND IMPROVEMENTS TO DATE

There has been a 20% reduction in the system main break frequency rate over the 15 years of the MRRP. The rising break trends of the 1980s and 90s were brought under control and reversed. The result has been a downward bending of the main break and leak curves, resulting in an estimated reduction of 140 main breaks per year, and representing $420,000 in annual cost savings.

V. LESSONS LEARNED

Some of the lessons learned from asset management activities and planning include the following:

- Getting started – working with project managers to build new techniques and justification.
- Collecting data has been a key foundation of MRRP success.
- There needs to be common cost and performance data in place throughout the company.
- Consistency of information flow through the organization has been undervalued.
- The building of standard definitions and terminology will facilitate communication and build the program.

VI. FUTURE PLANNED ASSET MANAGEMENT ACTIVITIES

LWC is in the process of carrying the message and ideas of asset management into the operating groups.

Bret Russell has been tasked with developing a coordinated asset management approach to all facets of LWC underground assets. Ed Basquill will coordinate asset management with the staff at both water plants for production and facilities, as well as for pumping and storage facilities.

Because 2007 is the final year of the current MRRP program, LWC aims to complete the objectives by targeting unlined water mains for removal. The 2007 MRRP focuses primarily on four types of replacement and rehabilitation:

- Replacement of unlined water mains and high-maintenance water mains (typically water mains installed from 1862 to 1865 and from 1926 to 1931) with polyethylene-encased cement-lined ductile iron, PVC, or HDPE water mains.
- Rehabilitation of structurally sound water mains, 6-inch through 12-inch diameters, by means of cathodic protection through the attachment of sacrificial magnesium anodes.
- System grid connections of dead-ended or poor circulating mains.
- Cut, plug, and abandonment of unlined cast iron water mains that no longer provide service or meet a hydraulic need.

LWC staff continues to develop new objectives and strategies for the next generation of MRRP. Staff anticipates that additional main replacement and rehabilitation efforts will be necessary to address such issues as aging cement-lined water mains, shifts in maintenance needs, asbestos-cement, corrosion hot spots, high-risk areas, lead services, fire hydrant spacing, plant piping, dead ends, and grid-ties, etc. There are also additional sections of unknown, unlined cast iron water mains in the system, especially from acquired water districts merged into LWC over the past 50 years.

ASSET MANAGEMENT PRACTICES
NEWPORT NEWS WATERWORKS

I. UTILITY PROFILE

Utility Name:

Newport News Waterworks

Utility Contact Person:

Chris R. Basford, PE
Design Services
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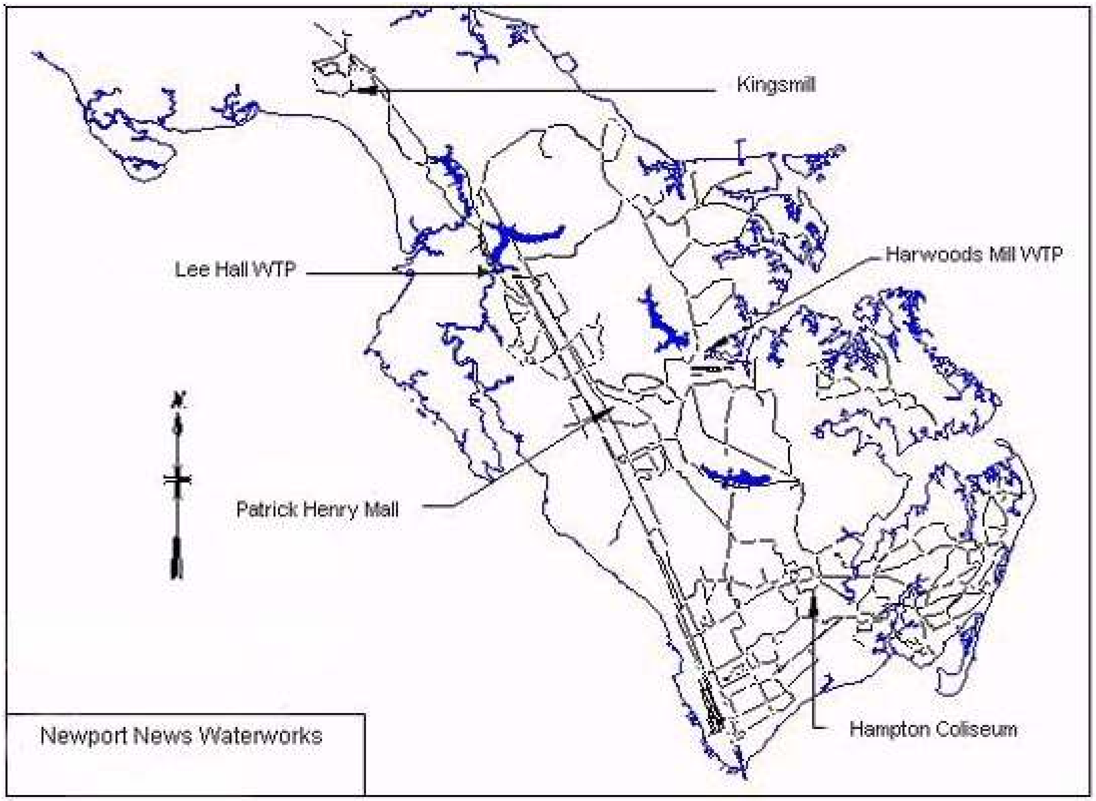
Services

Newport News Waterworks (Waterworks) is one of the 100 largest water utilities in the United States and rates among the three largest in Virginia. High-quality drinking water is provided to nearly 400,000 residents of the cities of Poquoson, Hampton, Newport News, and portions of York and James City Counties. Waterworks' 372 regular, full-time employees, divided into six functional divisions, provide the expertise and knowledge to accomplish Waterworks' goals and objectives.

Waterworks' primary source of raw water is the Chickahominy River. Secondary sources and storage include five reservoirs: Diascund Creek, Little Creek, Skiffe's Creek, Lee Hall, and Harwood's Mill. A sixth reservoir is currently proposed on Cohoke Creek in King William County. Waterworks operates two water treatment plants, Lee Hall and Harwood's Mill.

Newport News Waterworks' distribution system has over 1,700 miles of pipelines, consisting of 1-inch to 54-inch-diameter pipes. There are four pump stations. The types of pipelines in the distribution system are ductile iron, cast iron, concrete, polyvinyl chloride (PVC), galvanized iron, and steel. Currently, ductile iron, PVC (Schedule 80), and high-density polyethylene (HDPE) are being installed in the distribution system. Waterworks would consider concrete for larger-diameter pipelines, but most of the recently installed pipelines have been smaller-diameter lines.



Population Served:

Newport News Waterworks serves approximately 400,000 people within its service area.

Number of Customers:

There are approximately 123,887 water customers within the service area of Waterworks.

Size:

Currently, the average treated water at both plants is approximately 45 MGD; the peak treated flow rate is approximately 65 MGD. The combined treatment capacity at both plants is approximately 110 MGD.

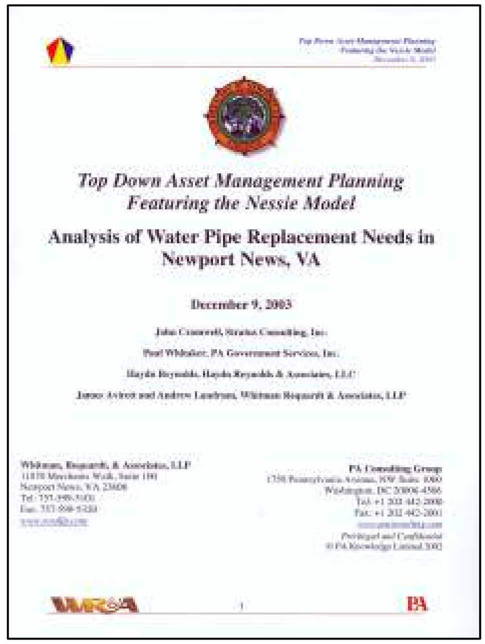
II. DEFINED DISTRIBUTION SYSTEM ASSET MANAGEMENT PROGRAM GOALS

This case study addresses Waterworks' Asset Management Program for its water distribution system (i.e., the treatment plants will not be discussed). The overall goal of the Asset Management Program is to continue to deliver quality water to customers, maintain fire fighting capabilities within the distribution system, and minimize customer complaints while being a good steward of public funds.

At this time, Waterworks does not have a written and defined Asset Management Program, nor does it have a designated "Asset Manager" of record. The Division Managers and Branch Managers make the asset management decisions for the organization.

However, Waterworks undertook a "Top Down Asset Management Planning" program in 2003 to plan the replacement/repair of system-wide pipelines using the Nessie Curve approach. This technique uses the utility's own data and operating knowledge to forecast the replacement expenditure of the aging facilities.

The results of this endeavor were published in December 2003 in a report, *Top Down Asset Management Planning, Featuring the Nessie Model, Analysis of Water Pipe Replacement Needs in Newport News, Virginia* (the Nessie ModelTM) by Whitman, Requardt & Associates, LLP and PA Consulting Group (the Consultants).


Top Down Asset Management Planning
Featuring the Nessie Model

Analysis of Water Pipe Replacement Needs in Newport News, VA

December 9, 2003

Whitman, Requardt, & Associates, LLP

PA Consulting Group

The report outlines the results of applying these tools and approaches to the Waterworks' system to provide a preliminary indication of the asset management challenges facing this organization.

III. HISTORY AND STATUS OF ASSET MANAGEMENT PROGRAM

Asset Inventory and Hierarchies and Condition Assessment

Waterworks' asset inventory data is maintained in several applications detailed below under "Use of IT Solutions to Develop the Pipeline Replacement Priority List." The data in these applications are being merged in one GIS-based asset registry that models all of the assets in the distribution system, and contains unique asset IDs.

During the course of development of the Nessie ModelTM by the Consultants, three types of input information were gathered:

Profile data with which to characterize the type, age, amount, and replacement value of pipe.

Operating data to characterize current trends in breaks, repairs, and replacements.

Operating experience and intuition regarding the overall performance of the asset, useful in assessing asset economic life and the rate of wear-out.

The Consultants conducted two workshops to gather and integrate input from the asset management team, and to review and revise the assumptions made during the data gathering phase regarding "economic life" of each category of pipe and the rate of wear-out of each asset. These revised approximations were used to develop the replacement needs of the pipeline system.

The following exhibits from the Nessie ModelTM present a tabulation of the total number of miles of pipe, by type and by diameter, that exist within the system by length and in percentage terms.

Exhibit 4.1 Miles of pipe by type by diameter

Diam	A	C	D	G	I	P	S	V	R	Total
1		0		1						1
2		0		**160**	7	7		**24**		**198**
3		0	0	0	0					0
4	1		**171**		**51**	0	0	0		**222**
6	1		2	0	**71**	0	0			74
8	3		**468**		**338**		0	4	0	**812**
10			0		5					5
12			**128**		**50**			1		**179**
14			0		4					4
16			**31**		**12**				0	43
18			1		**15**		0		0	16
20			2		**13**		0		5	20
24			4		**14**				**10**	27
27									4	4
30			**12**		**14**		0		4	30
34									4	4
36			4						0	4
42			2						0	2
48			3				1		4	8
54									2	2
99										0
Total	4	0	**829**	**161**	**593**	7	1	29	32	1657

KEY: A = AC pipe; C = Copper; D = Ductile; G = Galvanized; I = Cast Iron; P = new PVC; S = Steel; V = old PVC; R = PCCP

Exhibit 4.2 Pipe percentage by type by diameter

Diam	A	C	D	G	I	P	S	V	R	Total
1		0.00		0.00						0.00
2		0.00		**0.10**	0.00	0.00		**0.01**		**0.12**
3		0.00	0.00	0.00	0.00					0.00
4	0.00		**0.10**		**0.03**	0.00	0.00	0.00		**0.13**
6	0.00		0.00	0.00	**0.04**	0.00	0.00			**0.04**
8	0.00		**0.28**		**0.20**		0.00	0.00	0.00	**0.49**
10			0.00		0.00					0.00
12			**0.08**		**0.03**			0.00		**0.11**
14			0.00		0.00					0.00
16			**0.02**		**0.01**				0.00	**0.03**
18			0.00		**0.01**		0.00		0.00	**0.01**
20			0.00		**0.01**		0.00		0.00	**0.01**
24			0.00		**0.01**				**0.01**	**0.02**
27									0.00	0.00
30			**0.01**		**0.01**		0.00		0.00	**0.02**
34									0.00	0.00
36			**0.00**						0.00	0.00
42			0.00						0.00	0.00
48			0.00				0.00		0.00	0.00
54									0.00	0.00
99										0.00
Total	0.00	0.00	**0.50**	**0.10**	**0.36**	0.00	0.00	**0.02**	**0.02**	1.00

KEY: A = AC pipe; C = Copper; D = Ductile; G = Galvanized; I = Cast Iron; P = new PVC; S = Steel; V = old PVC; R = PCCP

Diameter is in inches.

Top Down Asset Management Planning, Featuring the Nessie Model **(December 9, 2003; Whitman, Requardt & Associates, LLP and PA Consulting Group)**

Using the Nessie ModelTM, the Consultants developed the replacement value for the inventoried pipelines. The unit cost estimates shown below were developed by the Consultants based on data supplied by Waterworks from actual experience, and include indirect costs. The cost estimates do not include service and hydrant replacement, since these costs are not included in the NNWW budgeting convention for capital projects.

Exhibit 4.3 Unit Costs for Replacement 9/12/2003									
Diameter	2"	4"	6"	8"	12"	16"	24"	36"	48"
	$/LF								
Cost/LF	$36.00	$44.00	$48.00	$56.00	$72.00	$104.00	$168.00	$240.00	$280.00
Cost/LF/InDia	$18.00	$11.00	$8.00	$7.00	$6.00	$6.50	$7.00	$6.67	$5.83
Engr & Admin (20%)	$7.20	$8.80	$9.60	$11.20	$14.40	$20.80	$33.60	$48.00	$56.00
TOTAL	$43.20	$52.80	$57.60	$67.20	$86.40	$124.80	$201.60	$288.00	$336.00

Exhibit 4.4 Weighted Average Replacement Costs	$/LF
36-54 in Prestressed Concrete Cylinder Pipe (PCCP)	$352.57
48 in Steel Pipe (STL)	$336.00
>24 in Ductile Iron Pipe (DIP)	$279.94
>24 in Cast Iron Pipe (CIP)	$259.20
18-30 in Steel Pipe (STL)	$235.39
16-30 in Prestressed Concrete Cylinder Pipe (PCCP)	$209.06
18-24 in Ductile Iron Pipe (DIP)	$186.24
18-24 in Cast Iron Pipe (CIP)	$175.23
10-16 in Ductile Iron Pipe (DIP)	$94.08
10-16 in Cast Iron Pipe (CIP)	$93.02
>4 in PVC (new)	$71.42
6-8 in Ductile Iron Pipe (DIP)	$67.20
6-8 in Cast Iron Pipe (CIP)	$65.57
Asbestos Cement Pipe (AC)	$62.64
4-8 in Steel Pipe (STL)	$61.54
6 in PVC Pipe (old)	$57.60
4 in Ductile Iron Pipe (DIP) and Copper	$52.80
1-3 in Galvanized Iron Pipe (GIP)	$50.16
1-4 in Cast Iron Pipe (CIP)	$50.16
2-4 in PVC (new)	$50.16
2-4 in PVC (old)	$50.16

Risk/Criticality Assessment

Economic life and decay rate assumptions were made by the Consultants taking into account the input from the workshops and Waterworks staff.

> *"Economic life is defined as the trade-off point at which the present value of the pipe replacement investment is equal to the present value of the projected future stream of break repair costs to be incurred if the pipe is left in service"* (*Top Down Asset Management Planning, Featuring the Nessie Model*; December 9, 2003; Whitman, Requardt & Associates, LLP and PA Consulting Group).

The following exhibit depicts the economic life assumptions used by the Consultants.

Exhibit 4.15 Economic Life Assumptions

Asset Group ID	Units (Miles)	MEA Value	Economic Life	% E.L. realized	1 S.D. = x % E.L.	First Year of Replacement	Replacement Period	2003 replacement	2033 replacement
1-4in Pit CIP	4	0.94	90	100%	15%	1941	81	$26,000	$11,000
6-8in Pit CIP	34	11.89	150	100%	15%	1959	135	$7,000	$70,000
10-16in Pit CIP	24	11.55	170	100%	15%	1968	153	$2,000	$31,000
18-24in Pit CIP	24	22.12	180	100%	15%	1972	162	$8,000	$80,000
>24in Pit CIP	2	2.85	200	90%	15%	2009	162	$0	$1,000
1-4" Spun CIP	55	14.52	80	100%	15%	1969	72	$23,000	$361,000
6-8" Spun CIP	374	129.52	95	100%	15%	1974	86	$60,000	$1,609,000
10-16" Spun CIP	46	22.84	100	100%	15%	1977	90	$8,000	$251,000
16-24" Spun CIP	18	16.85	125	100%	15%	1988	113	$0	$33,000
>24" Spun CIP	12	16.27	150	90%	15%	1993	122	$1,000	$21,000
4in DIP & Coppe	69	19.10	60	100%	15%	1927	54	$3,000	$679,000
6-8in DIP	211	75.01	60	100%	15%	1982	54	$14,000	$2,747,000
10-16in DIP	73	36.47	65	100%	15%	1984	59	$5,000	$1,102,000
18-24in DIP	5	5.11	70	100%	15%	1987	63	$1,000	$86,000
>24in DIP	8	12.37	75	90%	15%	2000	61	$1,000	$249,000
4" Wrap DIP	103	28.63	75	100%	15%	2019	68	$0	$25,000
6-8" Wrap DIP	259	91.85	75	100%	15%	2019	68	$0	$71,000
10-16" Wrap DIP	86	42.92	80	100%	15%	2021	72	$0	$19,000
18-24" Wrap DIP	1	1.34	85	100%	15%	2023	77	$0	$0
>24" Wrap DIP	13	19.20	90	90%	15%	2023	73	$0	$2,000
1-3in GIP	137	35.82	70	100%	45%	1994	189	$752,000	$615,000
1-3" "poor" GIP	24	6.96	50	100%	45%	2028	135	$149,000	$144,000
PVC (old)	7	1.98	55	100%	30%	1994	99	$14,000	$51,000
2-4 PVC (new)	24	6.28	60	100%	15%	2007	54	$0	$7,000
>4in PVC (new)	5	1.98	70	100%	15%	2008	63	$0	$16,000
16-30in PCCP Class 3	20	21.67	125	100%	15%	1957	113	$3,000	$41,000
36-54in PCCP Class 3	27	49.43	150	90%	15%	1962	122	$2,000	$29,000
16-30in PCCP Class 4	2	2.73	60	90%	30%	2027	97	$11,000	$57,000
Asb Cement	4	1.40	75	100%	15%	1984	68	$2,000	$42,000
STL	2	2.15	70	100%	15%	1956	63	$4,000	$8,000
TOTALS	1,675	711.74						$1,096,000	$8,458,000

Waterworks' distribution system assets have not been formally prioritized by criticality.

Use of IT Solutions to Develop the Pipeline Replacement Priority List

Waterworks uses a number of applications that support the utility's asset management activities. These are as follows:

- Waterworks Inventory Control Management System (WICM) – This mainframe application holds work orders (time and material charges, failure codes) and storeroom inventory. It does not contain installed asset inventory. Work orders contain operational codes to indicate the type of work performed. Work orders are not associated with a specific asset. However, summary reports can be created indicating, for example, the ratio of reactive to planned work orders. This system was implemented in the 1980s, but contains data only back to 1997.
- BNA Fixed Assets – This commercial off-the-shelf (COTS) software package is used to compile asset inventory for GASB 34 compliance. For distribution pipe, BNA contains only the total length and is not broken down by material, size, or date installed. This system has no relationship to any other Waterworks' database.
- Geographic Information System (GIS) – The GIS contains the installed inventory of distribution pipe assets and a point feature class ("mainbreaks") that includes each pipeline repair. For each new pipeline repair, the geographic location is added

manually to the mainbreaks point feature class. Relevant attribute information from WICM and from the pipe layer in GIS are also saved in the mainbreaks point feature class. Data in mainbreaks are used for analyzing trends in pipeline repair, ultimately resulting in prioritization of pipeline replacement.

- RETIREMENTS – This in-house designed Microsoft® Access database is used to remove pipe, valve, and hydrant assets from the accounting asset inventory. This database mimics a manual procedure established in 1939 and has no relationships to other databases.
- Public Utility Property System (PUPS) – This mainframe application holds the asset inventory of installed valves and hydrants. There is a limited relationship between this and WICM.
- Waterworks Street File System (WWST) – This mainframe application holds an asset inventory of installed pipelines. There is no relationship between this database and WICM or Peachtree. WWST is no longer updated, but it is used for historical information.
- GIS (ArcView) – A map of water assets and other facilities is available to field personnel on laptop computers. Data on water main breaks is available. However, since WICM work orders are not logically linked to physical objects, information on most of the work performed is not available through this interface.

While these systems contain many components of a CMMS and create useful reports, there are two fundamental problems:

Since these are standalone systems, it is often necessary to enter information from one system into another. In some cases, the inventories are based on different data sources.

Since WICM work orders are not linked to a physical object, it is possible to establish performance histories only for classes of objects. A work-around solution for pipelines was created by adding some of the WICM data to GIS.

Waterworks' management is aware that the functionality provided by these applications can now be obtained from several COTS computerized maintenance management systems (CMMSs). It is the utility's intention to replace these applications with a COTS CMMS at some point in the future.

Waterworks uses ArcView shapefiles and database tables to create and manage the replacement pipeline priority list.

Projects are identified by a polygon surrounding the area to be worked. Projects are prioritized by a point system based on number of breaks, maintenance cost, and life expectancy.

Points are calculated using the following criteria:

Five points are assigned for each break.

Points are assigned for the age of pipe, based on the percent of life reached/25 (based on the age as defined by the Nessie ModelTM).

Points are assigned for cost based on the formula 100 * (cost breaks/cost to replace).

Points are not assigned for customer complaints because a complaint may not be attributable to a problem with the main.

Points are not assigned for corrosive soil because (1) if soil is corrosive it should show up as breaks, and (2) Waterworks does not currently have a good inventory of corrosive soil.
Utilities within projects by other City departments (e.g., street paving, etc.).
Water quality issues receive priority ranking (regardless of age or material of pipe).
Waterworks plans to include fire flow rate as a selection criteria in future phases of this program.

After computing the priority rankings, maps of 15 top projects are printed and reviewed. This review consists of assessing pavement and constructability issues. After this review, 10 projects are selected for further consideration. The next step in project evaluation is accomplished by the Newport News Fire Department. Once Fire Department approval has been obtained, the project is assigned to the next available designer.

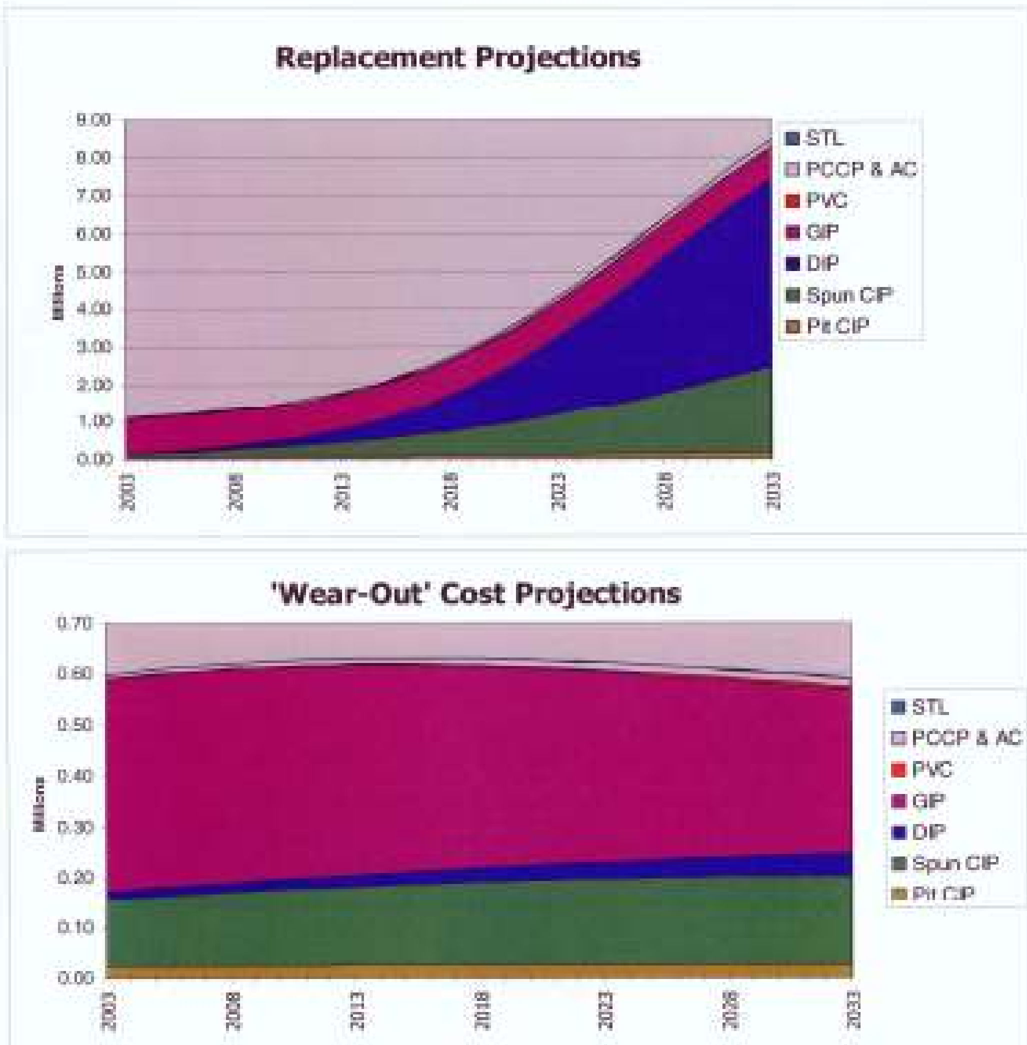
Capital and Renewal & Replacement Planning

The *Top Down Asset Management Planning, Featuring the Nessie Model* report (December 9, 2003; Whitman, Requardt & Associates, LLP and PA Consulting Group) concluded the following:

> *"The overall pattern in the Newport News Nessie Curves is similar to that observed in many other cities where the methodology has been applied. As a reflection of the gradual growth of the city over many decades, the replacement forecast has the shape of a ramp that rises gradually from the current $1 million level of annual expenditure to a level of about $8 million per year in 2033. After 2033, the rate of increase slows and a steady-state rate of replacement investment appears to be limited in 2073 at a level of $14 per year (2003 dollars)."*

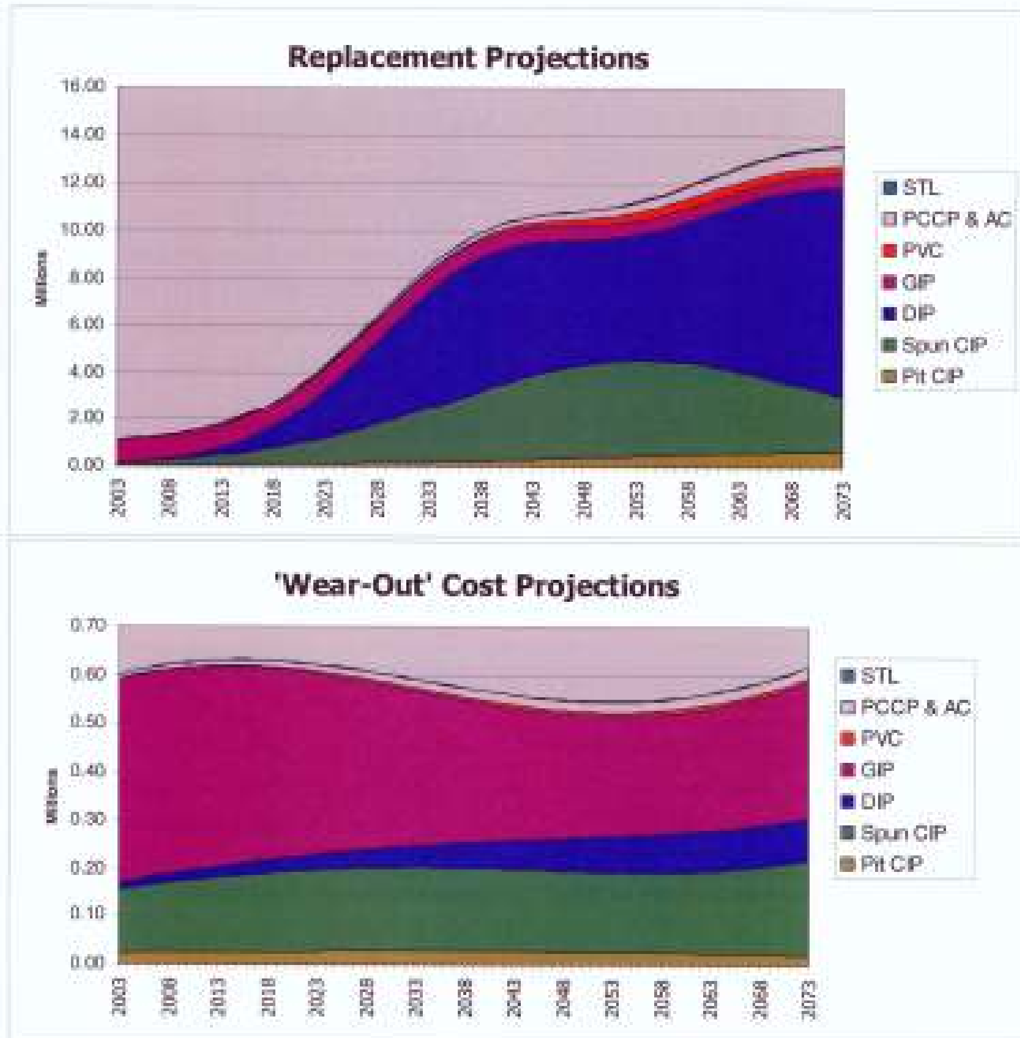
The following exhibits from the report cited above graphically depict the 30- and 70-year replacement projections, respectively.

Exhibit 5.1 Newport News Nessie Curves: 30-Year Forecast



Top Down Asset Management Planning, Featuring the Nessie Model **(December 9, 2003; Whitman, Requardt & Associates, LLP and PA Consulting Group)**

Exhibit 5.2 Newport News Nessie Curves: 70-Year Forecast



Top Down Asset Management Planning, Featuring the Nessie Model **(December 9, 2003; Whitman, Requardt & Associates, LLP and PA Consulting Group)**

Maintenance Management

As pipe failures occur, the failure locations are added to the GIS by the Leak Coordinator, then checked by Engineering. During the checking process, each new failure is reviewed to try to identify patterns based upon the pipe material, failure type (e.g., joint, pinhole), and proximity to other failures. When anything out of the ordinary appears, discussions are held between Engineering and Operations to plan the course of action. As the work order history indicates problems with a particular main or neighborhood, the associated pipe is added to the priority replacement program, as appropriate.

Main break histories back to 1994 are available in GIS for review and analysis. Asset replacement decisions are made in concert with needs identified in Waterworks' hydraulic model to support the asset management program goals and performance metrics. The hydraulic model is capable of modeling the fire flow available to each individual customer.

Most of the non-reactive work is asset replacement. Preventive maintenance consists of hydrant flushing and some valve operations (which Waterworks management would like to increase). Flow data from hydrant flushing is entered into Waterworks' hydraulic model for calibration. A unidirectional flushing program was piloted and abandoned. In the past, Waterworks has also done some predictive maintenance on large-diameter concrete pipe, but this has not become a standard procedure.

Purchasing and Inventory Management

Waterworks' material inventory is stored in WICM. While this results in some system limitations, management feels that storeroom inventory is appropriately controlled. Critical stock items have been identified and are separately maintained. Needed parts are generally available in stock.

Valuation and Depreciation Methodology

Waterworks is compliant with GASB 34, and does not use the modified approach. There are several databases that contain pipe and other water distribution asset inventories. The data in these databases are being merged into one GIS-based asset registry that models all of the assets in the distribution system. This model will not reconcile with the valuations in the BNA Fixed Asset system because only summary (i.e., project) level data are contained in BNA. If portions of projects have been retired, it is not practical to field-verify or correct the BNA Fixed Asset data.

Performance Management

Waterworks' performance metrics for asset management are focused on service to the utility's customers rather than on "traditional" tactical asset management measures. The performance measures reflect the distribution system asset management program goals, which are the following:

- Water availability/reliability, measured by leaks per mile and customer reports of leaks.
- Water quality, measured by Virginia Department of Health standards.
- Fire fighting capacity, based upon the utility's hydraulic model.

Costs, Savings, and Improvements to Date

Waterworks has been evolving its asset management program for more than 10 years. As distribution assets needing replacement have been identified and replaced, the metrics of leaks per mile and customer reports of leaks have been decreasing.

IV. LESSONS LEARNED

Asset replacement / rehabilitation needs to be based on a published matrix combining risk of failure with consequence of failure. Risk of failure should be established based on asset past performance, expected performance, and expected life. Consequence of failure should be based on number and type of customers affected and on water quality impact. In support of this, software must be capable of relating all work orders to the appropriate asset, maintaining a complete history of each asset, and generating detailed and summary reports of asset performance.

V. FUTURE PLANNED ASSET MANAGEMENT ACTIVITIES

Newport News Waterworks began a logical replacement of system-wide piping in the late 1980s using a combination of methods. Waterworks used a "point system" based on the number of leaks, pipe material, system pressure, etc., and on an "economic model" using the present worth of future repairs to determine whether it is cheaper to replace a pipeline or to continue the repair process.

Using the priority program mentioned above, a spreadsheet was used to develop the pipeline replacement priority program, requiring manual input of all data.

The spreadsheets were difficult to maintain and did not adequately address all of the pipelines. In 2004, Waterworks began to use its GIS system to identify projects and to update the priority rankings. The use of the GIS system to develop the list of projects was considered quite helpful.

Waterworks currently budgets approximately $1.5 million annually for distribution pipe replacement, but this expenditure will be gradually increased to $8.5 million over the next 30 years. Over the past 2 to 3 years, the funding levels have kept pace with the required level of pipeline replacement and Waterworks anticipates this trend to continue.

Waterworks plans to continue the use of the following planning documents developed over the past few years to methodically replace and/or rehabilitate its distribution system.

Top Down Asset Management Planning Featuring the Nessie Model (2003)
Distribution Pipeline Replacement Program (1987)
Distribution Pipeline Replacement Program (2004)

Waterworks is also in the process of increasing the level of detail in the data collected by field personnel responsible for repair of line breaks, leaks, and replacement of pipes selected for rehabilitation under this program. The goal of this effort is to develop a database of known pipe failures and the related cause by pipe material and application for use in predicting the future behavior of underground assets. As an additional step in increasing the level of data collected in the field, Waterworks has future plans to upgrade its existing work order system.

Additional planned changes to improve the Asset Management Program are the following:

- Relating all asset management transactions (i.e., work orders, inspections, condition data, preventive maintenance schedules) to a physical asset.
- Improving asset management data quality through more extensive edits, validations, and controls during data entry.
- Centralizing the role of GIS as Waterworks' asset registry and tool for analysis.
- Improving the information available to Waterworks' field staff, and incorporating its data corrections and suggestions into the asset management program.

APPENDIX D

DETAILED DESCRIPTIONS OF PROPOSED RESEARCH PROJECTS

RESEARCH AREA 1 – ASSET MANAGEMENT FRAMEWORK/MODELS FOR ORGANIZATIONS

Project 1.1: Policies and Strategies to Implement Asset Management (AM) Programs

Project Description

Objective(s):
1. Develop a conceptual framework specific to North American Water Utilities for implementing and managing an Asset Management Program.
2. Identify policies required to support Asset Management (e.g., financial/rates, life-cycle costing, triple bottom line, condition-based, etc.).
3. Develop policies and strategies that are adaptable to water utilities of a wide range of sizes.

Approach:
This research should build on and extend guidelines articulated in *Implementing Asset Management: A Practical Guide* (AMSA et al. 2007). The proposed research project will develop a conceptual framework that utilities can use to select a course of action, as well as identify a preferred approach to set policy and implement these strategies. The tasks to be accomplished include, but are not limited to the following:

Task 1. Survey U.S. and international utilities and other organizations in asset-intensive industries to identify and document conceptual frameworks utilized to implement asset management policies and strategies such as the NRC Canada's *Framework for Municipal Infrastructure Management* (Vanier et al. 2006). Document key attributes and content of applicable frameworks.

Task 2. Benchmark asset management policies used in North American water utilities against best practices used in other utilities and asset-intensive industries. Identify factors unique to North American utilities that must be considered in establishing an asset management framework.

Task 3. Document key policy areas and strategies to be considered in the framework, their relevance to water utilities, and their application in other similar environments.

Task 4. Assemble a work group of experts from utility, regulatory, policy, academia and research organizations to participate in a set of collaborative brainstorming sessions and workshops to develop a conceptual framework and a broad set of policies and strategies to be considered for implementation. The work group should address variations in framework, policy and strategy for utilities of various sizes.

Task 5. Phase 1 Report: Document a conceptual framework for implementing and managing an Asset Management Program.

Task 6. Phase 2 Report: Develop a Guidance Document on implementing an Asset Management Program using the conceptual framework including:

- Key policy requirements: Address financial planning and rate structures, accounting, levels of service, risk, health and safety, environmental, regulatory, human resources, reporting and sustainability. Include examples and guidance on key aspects of each policy statement.

- Guidelines for translating policies into implementation strategies: address key issues around data, technology, and organization.
- Recommended implementation strategies: Consider scalability and adaptability to apply strategies across various sizes of utilities.

Note: Coordinate with Research Area 5, Project 5.1, Information Technology Integration and Data Model to Support Asset Management.

Rationale:
The North American water industry needs a standard conceptual framework to assist utilities in defining and implementing their asset management policies and strategies. This framework must address the unique needs of water and wastewater utilities in North America. A conceptual framework will help utilities effectively implement successful asset management programs and expand the use of best practices in establishing policies and implementing strategies. This approach could facilitate the adoption of a common asset management framework based on successful asset principles, and proliferate these concepts across the industry. The framework could also be a driver for discussing and possibly establishing a national policy on asset management in the water and wastewater industries.

Benefits/Industry Value:

- Establishes a conceptual framework for application of asset management policies and strategies that is scalable to water utilities of various sizes.
- Identifies policy priorities for building and maintaining an asset management program.
- Provides guidance on how a utility establishes an asset management program.

Total Estimated Project Duration: Phase 1: 18 months, Phase 2: 12 months

Estimated Project Cost: Phase 1: $200,000, Phase 2: $150,000, Total $350,000

Research Area 1 – Asset Management Framework/Models for Organizations

Project 1.2: Organizational Attributes of Effective Asset Management Programs

Project Description

Objective(s):

1. Identify and clearly define organization models that support effective AM programs.
2. Define organizational elements and attributes required for successful AM program implementation.
3. Define required skills and organizational capabilities.
4. Develop strategies to integrate asset management practices into an effective organization including change management.
5. Develop organization characteristics and strategies that are adaptable to water utilities of various sizes.

Approach:

This research should evaluate relative effectiveness of various organization models used in utilities and other asset-intensive industries and assess the applicability of these models to North American utilities. Specifically, international utilities and research in Australia and the United Kingdom should be studied. The tasks to be accomplished include but are not limited to the following:

- Task 1. Survey North American water utilities to determine the various organization models currently used for asset management.
- Task 2. Review organization models used by best-in-class international utilities and asset-intensive industries. Compare and contrast with organizational models used in most North American water utilities.
- Task 3. Develop a preliminary technical report on the elements and implementation strategies used in asset-centric organizations including structure, roles, skills, accountability, and reward. Include a straw man of relevant organization models and elements along with the barriers and challenges to implementation of each.
- Task 4. Conduct a two-day workshop to assess, validate and refine the preliminary technical report with input from utility staff representing human resources and asset management as well as subject experts in organizational development. Define alternative organization models and structures to address variations in utility size and service model. The purpose of the workshop is to consider which organization models, elements, strategies and characteristics used in industry are most applicable to the political, cultural, and collective bargaining environment of the North American water industry.
- Task 5. Document the organizational models, strategies and characteristics of successful asset management programs in a guidance manual that includes tools and techniques for assessing organization readiness and implementing business process, culture change and performance metrics.

Rationale:
Conventional utility organization models and structures were developed to support transactional processes related to delivering internal and external services (i.e., accounting, engineering, operations, maintenance, customer service, etc.). Utilities need a set of effective organization models and characteristics that support the implementation of a cross-functional asset management program. This project will identify organization models that are adept at working across silos, removing barriers, increasing efficiency and improving performance.

Benefits/Industry Value:

- Saves time and effort of individual utilities conducting redundant research on various organizational models.
- Establishes a set of asset management organization models, structures and elements for use by utilities along with an implementation guidance manual.
- Proven organization models will improve the adoption rate of asset management policies and best management practices by utilities.

Total Estimated Project Duration: 24 months

Estimated Project Cost ($): $300,000

Research Area 1 – Asset Management Framework/Models for Organizations

Project 1.3: **Prepare Guidance Manual on Level of Service and Metrics**

Project Description

Objective(s):

1. Determine standard level-of-service metrics and key performance indicators (KPIs) to meet customer, environmental, financial and stakeholder expectations related to asset management.
2. Develop practical guidance and implementation strategies required to achieve desired asset management service levels.
3. Identify the role of Information Systems in accurate, reliable, and timely reporting.

Approach:

This research project should identify and extend numerous research sources that include levels of service such as QualServe, the *International Infrastructure Management Manual* (IPWEA 2006), Service Level Agreements used in other industries, and applicable research such as AwwaRF's *Triple Bottom Line Reporting of Sustainable Water Utility Performance* (Kenway et al. 2007) and *Selection and Definition of Performance Indicators for Water and Wastewater Utilities* (Crotty 2003), AWWA's report *Benchmarking Performance Indicators for Water and Wastewater Utilities* (Lafferty and Lauer 2005) and *Benchmarking Performance Indicators for Water and Wastewater Utilities: 2006 Annual Survey Data and Analysis* Report (Lafferty and Lauer 2007), IWA's *Performance Indicators for Water Supply Services* (Alegre et al. 2006) . The tasks to be accomplished include but are not limited to the following:

Task 1. Conduct literature and case study reviews of methodologies and practices used for implementing service levels in U.S. and international utilities and other industries using service level agreements, including asset-intensive industries and IT industries.

Task 2. Determine applicability and transferability of level-of-service methodologies used in utilities and other industries.

Task 3. Conduct a comprehensive survey of level of service metrics and KPIs used throughout the water industry and the information systems used to manage and report performance data.

Task 4. Convene an expert team to establish consensus and common definitions related to:

- Appropriate level-of-service metrics and KPIs to be considered for use by North American water and wastewater utilities.
- A set of strategies to guide the effective development and implementation of level-of-service agreements, systems and practices.

Task 5. Document level of service metrics and KPIs in a guidance document, including an implementation framework and strategies for organization, policy, practices, and systems.

Rationale:
A standard service level framework and set of measures specific to asset management for North American utilities does not currently exist. Asset management and resource decisions need to be informed and driven by an understanding of customer desires for levels of service, regulatory requirements, utility performance, cost and rate impact information (willingness to pay), environmental policy and local economic support. Setting standard metrics allows for benchmarking and comparison across the industry.

Benefits/Industry Value:

- Sets standard metrics and KPIs that lead to positive changes in service levels.
- Guides utilities on the purpose and value of service level agreements.
- Improves decision making related to capital asset investments.
- Supports service level benchmarking to utility and other industries.

Total Estimated Project Duration: 24 months

Estimated Project Cost: $300,000

Research Area 2 – Risk Management

Project 2.1: **Risk Management Protocols Supporting Capital Investment Decisions**

Project Description

Objective(s):

1. Identify categories of risk encountered in asset management decision making, including financial, social and environmental risks (triple bottom line).
2. Review techniques for assigning values to risk in a cost-benefit framework.
3. Explore mitigation techniques for different risk categories.
4. Develop risk management framework for managers to make effective asset management decisions.

Approach:

The approach should build on the findings of AwwaRF's *Triple Bottom Line Reporting of Sustainable Water Utility Performance* (Kenway et al. 2007). In addition, the project should be coordinated with ongoing GWRC projects (cofunded by AwwaRF) "Tool for Risk Management of Water Utility Assets." (UKWIR In Progress (a)) and "Tool for Benefit Cost Analysis" (WERF In Progress). The approach should include but not be limited to the following tasks:

Task 1. Conduct literature search on risk analysis and risk management methods, covering financial, social and environmental risks (international and North American utility review).

Task 2. Survey utilities for use of risk management categories and identify general categories of mitigation methods.

Task 3. Develop case studies of risk management framework/methodology currently in place.

Task 4. Conduct workshop with utility and industry experts to review and develop the risk types, analysis and management methods and establish a framework for risk management. Consider the four quadrants of risk assessment:

- High Consequence – High Probability
- High Consequence – Low Probability
- Low Consequence – High Probability
- Low Consequence – Low Probability

Task 5. Beta test the framework/methodology for three participating utilities (i.e., spreadsheet methodology to assist utilities in risk management planning).

Task 6. Document the risk management framework for use by the water industry in a concise report and supporting material.

Rationale:

As utilities become more familiar with the basic principles of asset management, they will want to move to higher levels of sophistication. This project will build on existing AwwaRF's *Triple Bottom Line Reporting of Sustainable Water Utility Performance* (Kenway et al. 2007), and will establish a roadmap for utility managers to reduce long-term risk exposure and more reliably meet service level expectations. In addition, this study will demonstrate how triple bottom line principles apply to risk management for capital investments.

Benefits/Industry Value:

1. Reduces risk profile for utility.
2. Helps avoid adverse impacts to customers, communities and environment.
3. Improves transparency in decision making process.
4. Improves efficiency in use of capital (long term).
5. Improves environmental sustainability.
6. Improves responsiveness to customers and stakeholders.
7. Potentially improves bond ratings.

Total Estimated Project Duration (months): 30 months

Estimated Project Cost($): $400,000.
Utilities should be encouraged to pay for their travel to workshop as part of in-kind services to enable more effort to be placed on gathering and documenting information for utility use.

Research Area 3 – Condition Assessment and Performance Monitoring

Project 3.1: **Workshop and Synthesis Document on Condition Assessment of Prestressed Concrete Cylinder Pipe (PCCP).**

Project Description

Objective(s):

1. Conduct a workshop to gain input from and to update users on the effectiveness of the latest condition assessment techniques for PCCP.
2. Develop synthesis document on PCCP based on literature review, workshop, and input from utilities focusing on condition assessment and performance monitoring.

Approach:

This project should ideally be conducted in cooperation with the Bureau of Reclamation and other major stakeholders and should build on AwwaRF's funded reports like *Workshop on Condition Assessment Inspection Devices for Water Transmission Main* (Lillie et al. 2004) and *Electromagnetic Inspection of Prestressed Concrete Pressure Pipe* (Mergelas and Kong 2001). It should be coordinated with the ongoing AwwaRF research like "Failure of Pre-Stressed Concrete Cylindrical Pipe" (Boyle Engineering Corp. In Progress). The approach should include but not be limited to these tasks:

Task 1. Develop White Paper documenting the issues related to failure modes, condition assessment techniques, and performance monitoring of PCCP.

Task 2. Conduct intensive 2-day workshop with utilities, experts in the field of condition assessment, and other stakeholders to discuss and document condition assessment techniques including their effectiveness, weak points, false identification, costs and other pertinent factors.

Task 3. Develop case studies based on field experiences by utilities and other stakeholders, focusing on condition assessment and performance monitoring of PCCP.

Task 4. Develop synthesis document summarizing the state-of-the-art in PCCP condition assessment and performance monitoring to include results of the White Paper, case studies, and workshop; and prepare a needs assessment for future research needs or tools.

Rationale:

PCCP has been widely used in the utility industry and in federally sponsored projects for conveying large quantities of both raw and finished water. Pipe failures are infrequent, but the consequences can be quite serious in nature. Several studies have been conducted on failure modes and condition assessment techniques. Further, there is significant recent experience by utilities and other stakeholders on the application and effectiveness of condition assessment techniques. This information needs to be consolidated and put into a form that can be quickly disseminated and used by the interested stakeholders.

Benefits/Industry Value:

1. Utilities and stakeholders can share information and get the latest technical information on PCCP.
2. Synthesis document will consolidate key findings for ready use by industry.
3. Would identify gaps in knowledge and tools that can be used as the basis for planning future needs and research.

Total Estimated Project Duration (months): 18 months

Estimated Project Cost ($): $150,000

Research Area 3 – Condition Assessment and Performance Monitoring

Project 3.2: Develop Guidance Manual for Condition Assessment of Water Main Appurtenances

Project Description

Objective(s):
1. Provide for uniform classification system of appurtenances.
2. Summarize or develop performance criteria for water main appurtenances (hydrants, valves, PRVs, service lines, air release valves, blow-offs, etc.).
3. Consolidate condition assessment information from previous efforts and develop guidance manual.

Approach:
This project needs to build upon the following AwwaRF projects: *Installation, Condition Assessment, and Reliability of Service Lines* (Le Gouellec and Cornwell 2007); *Potential Techniques for the Assessment of Joints in Water Distribution Pipelines* (Reed et al. 2006); *Key Criteria for Valve Operation and Maintenance* (Rosenthal et al. 2002); *Performance and Life Expectancy of Elastomeric Components in Contact With Potable Water* (Rockaway et al. 2007); *Condition Assessment Strategies and Protocols for Water and Wastewater Utility Assets* (Marlow et al. 2007) and "Criteria for Optimized Systems" (HDR Engineering, Inc. In Progress (b)). The approach should include but not be limited to the following tasks:

- Task 1. Define the universe of appurtenances so the bounds and extent of the project are defined upfront.
- Task 2. Gather together the utility practices, manuals, AWWA Standards, manufacturers' literature and guidance related to water main appurtenances.
- Task 3. For each appurtenance, define best practices for condition assessment and performance monitoring.
- Task 4. Gain practical utility input on the various recommended practices and revise the practices accordingly.
- Task 5. Prepare draft and final reports summarizing project findings.

Note: Coordinate with Research Area 6, Project 6.1, Guidance Manual for Best Maintenance Practices for Water Distribution Assets.

Rationale:
Utilities deal with dozens of water main appurtenances in their distribution system on a daily basis. AWWA, AwwaRF, equipment manufacturers, suppliers, the engineering community, and others have developed various standards, practices and various reports for individual water main appurtenances; however, there is no readily available, single reference that consolidates the information in one place. Thus, the utility operator has to go to numerous locations to find information.

Benefits/Industry Value:
This project will:
1. Improve consistency in use of criteria and methods for condition assessment for appurtenances.
2. Assist utilities with developing appropriate maintenance plans.
3. Help ensure compliance with the International Standards Organization (ISO).
4. Provide consistent criteria for benchmarking.
5. Provide a uniform method for classifying appurtenances.

Total Estimated Project Duration (months): 30 months

Estimated Project Cost ($): $350,000

Research Area 4 – Decision Making for Capital Improvement Plans (CIP) and Replacement and Renewal (R&R)

Project 4.1: Develop and Validate Degradation Curves for Buried Water Distribution System Assets

Project Description

Objective(s):

1. Determine factors that influence deterioration in order to categorize assets and associated degradation curves.
2. Present knowledge base in the form of decay curves with validation information.

Approach:

The project approach will include a review and summary of the existing information for key underground asset classes, review and comment by a panel of experts on decay curves, methods for selecting or adjusting the applicable decay curves for use by the utility, and preparation of the draft and final reports. The tasks should include but not be limited to the following:

Task 1. Identify and summarize factors that cause underground water distribution system assets to fail. There are several factors that cause underground assets to fail including inadequate bedding, vibration, traffic or other loads, hydraulic surges, stray currents, water quality degradation, tuberculation, leaks, joint separations, valves that are inoperable, plus dozens of others. This task will categorize and summarize the affected failure modes and asset classes.

Task 2. Identify the top four asset classes to be evaluated. Identify the top four asset classes to be evaluated and provide rationale for selection. Gain AwwaRF and PAC approval of these classes for further definition.

Task 3. Prepare decay curves. By literature review and survey techniques, gather information on the life of the selected asset classes. Prepare a range of decay curves based on failure causes or other factors.

Task 4. Critique the draft decay curves by a peer review process. Assemble a panel with expertise in the selected asset classes and facilitate a critical review of the information provided. Have the panel provide written comments on their suggested revisions.

Task 5. Revise the decay curves and provide guidance on use. This task will include revising the decay curves and providing examples on how to use them, including how to tailor them for a more accurate portrayal of an individual utility's situation.

Task 6. Prepare reports. Prepare draft and final reports.

This work should be coordinated with ongoing and planned work from WERF and the AWWA Standards Committees. Further, UKWIR's National Mains Failures Database (Hale et al. 2006) may be a useful source of background information.

Rationale:
The basis for implementing an asset management program is understanding the function and life of the assets being considered. The functions are well understood, but the expected lives of various classes are not well defined and are driven by a multitude of physical, chemical and hydraulic factors. While research has identified many causes of pipe failure, additional knowledge is needed on the rate of decay of all buried assets, including different types of pipes and appurtenances. This information is needed to plan maintenance, repair and rehabilitation programs.

Benefits/Industry Value:
1. Enables utilities to more accurately estimate performance, degradation and failure.
2. Improves estimates of remaining service life.
3. Optimizes rate-of-return from investments in repair, rehabilitation and replacement.
4. Reduces risk of catastrophic failure.
5. Assists vendors in developing improved manufacturing processes for pipes, appurtenances, etc.

Total Estimated Project Duration (months): 36 months

Estimated Project Cost ($): $350,000

Research Area 4 – Decision Making for Capital Improvement Plans (CIP) and Replacement and Renewal (R&R)

<u>Project 4.2:</u> Develop and Validate Degradation Curves for Aboveground Water Distribution System Assets

<u>Project Description</u>

Objective(s):

1. Determine factors that influence deterioration in order to categorize assets and associated degradation curves.
2. Present knowledge base in the form of decay curves with validation information.

Approach:

The project approach will include a review and summary of the existing information for key aboveground asset classes, review and comment by a panel of experts on decay curves, methods for selecting or adjusting the applicable decay curves for use by the utility, and preparation of the draft and final reports. The tasks should include but not be limited to, the following:

Task 1. Identify and summarize factors that cause aboveground water distribution system assets to fail. There are several factors that cause aboveground assets to fail including vibration, hydraulic surges, vandalism, being struck by motor vehicles, overheating, water quality degradation, freezing, leaks, corrosion, plus others. This task will categorize and summarize the affected failure modes and asset classes.

Task 2. Identify the top four asset classes to be evaluated. Identify the top four asset classes to be evaluated and provide rationale for selection. These may include, but not be limited to finished water storage facilities, pump stations, standpipes, rechlorination stations, fire hydrants, and others. Gain AwwaRF and PAC approval of these classes for further definition.

Task 3. Prepare decay curves. By literature review and survey techniques, gather information on the life of the selected asset classes. Prepare a range of decay curves based on failure causes or other factors.

Task 4. Critique the draft decay curves by a peer review process. Assemble a panel with expertise in the selected asset classes and facilitate a critical review of the information provided. Have the panel provide written comments on their suggested revisions.

Task 5. Revise the decay curves and provide guidance on use. This task will include revising the decay curves and providing examples on how to use them, including how to tailor them for a more accurate portrayal of an individual utility's situation.

Task 6. Prepare reports. Prepare draft and final reports.

This work should be coordinated with ongoing and planned work from WEF and AWWA Standards Committees.

Rationale:
The basis for implementing an asset management program is understanding the function and life of the assets being considered. The functions are well understood, but the expected lives of various classes are not well defined and are driven by a multitude of physical, chemical, electrical and hydraulic factors. While research and past experiences have identified many causes of aboveground asset failures, additional knowledge is needed on the rate of decay of aboveground assets. This information is needed to plan maintenance, repair and rehabilitation programs.

Benefits/Industry Value:
1. Enables utilities to more accurately estimate performance, degradation and failure.
2. Improves estimates of remaining service life.
3. Optimizes rate-of-return from investments in repair, rehabilitation and replacement.
4. Reduces risk of catastrophic failure.
5. Assists vendors in developing improved manufacturing processes for aboveground assets.

Total Estimated Project Duration (months): 36 months

Estimated Project Cost ($): $350,000

Research Area 4 – Decision Making for Capital Improvement Plans (CIP) and Replacement and Renewal (R&R)

Project 4.3: Central Repository of Asset Data to Support Maintenance, Repair, Rehabilitation and Replacement (MRRR) for Water Mains

Project Description

Objective(s):

- Assess the feasibility and industry demand for a central repository to collect and trend water main failure data for use by utilities in determining their future CIP and MRRR spending.
- Develop alternative delivery, management, and financial models to support ongoing data collection and management services for a central repository.

Evaluate relevancy and applicability of the UKWIR's National Mains Failures Database (Hale et al. 2006).

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Approach:
This project will develop the need, feasibility and business case for a central repository of water main failure data and determine if and how the system should be developed, managed, financed and populated. Similar systems, including the UKWIR's National Mains Failures Database (Hale et al. 2006). should be evaluated.

Task 1. Survey the use and effectiveness of similar data-sharing systems for infrastructure assets, specifically for water or sewer buried assets.

Task 2. Hold a workshop to determine the feasibility of a central repository being supported by U.S. water utilities. Define the objectives, scope, management structures, and contributing agencies that should be considered. Define the breadth of content to be considered beyond failure data, including degradation curves, analytical tools, and decision criteria and guidelines. This project should be closely coordinated with AwwaRF/WERF's *SIMPLE ver 1.1* (GHD In Progress) to ensure alignment and to avoid duplication. This workshop should define the approach to plan, define, design, build, operate/maintain and manage the repository.

Task 3. Evaluate alternative delivery and finance models and develop a report with a business case for a central repository, a high level implementation plan, and a set of recommendations supported by an action plan.

Rationale:
The availability of actual failure data and historical trends in water main failures for various types of pipe is a critical element for an MRRR decision framework for buried assets. By sharing failure data across the industry, key data sets can be developed to support utilities in determining their future spending requirements for water mains. Previous asset management

workshops sponsored by USEPA in 2005 and WERF in 2002 also identified a need for a nationwide data repository on main breaks.

Benefits/Industry Value:

1. Provides central database of water main failure data for use by subscribing entities.
2. Assists utilities in establishing MRRR and CIP programs and justifying programs and expenditures to boards and customers.
3. Initiates process to establish industry standards for MRRR decisions, ultimately leading to benchmarking metrics.

Total Estimated Project Duration: 12 months

Estimated Project Cost: $100,000

Research Area 5: Asset Management IT and Data Management

Project 5.1: **Information Technology Integration and Data Model to Support Asset Management (Coordinate with Research Area 1, Project 1.1)**

Project Description

Objective(s):

1. Define the role of Information Technology (IT) in managing asset management business processes.
2. Identify systems integration approaches that demonstrate how component asset management systems can be integrated and assess opportunities to define standards for software development.
3. Establish a conceptual and logical data model and candidate IT integration approaches that can be adapted to various sized water utilities.

Approach:

This project should be coordinated with AwwaRF ongoing research like "Optimizing Information Technology Solutions for Water Utilities" (Red Oak Consulting In Progress), and should leverage existing water and sewer data models such as those available from ESRI. In addition, industry standards for IT integration and data models should be considered. The tasks to be accomplished include but are not limited to the following:

Phase 1: Develop IT Integration and Data Model Report

Task 1. Develop a technical paper to identify and evaluate existing and future systems integration alternatives required to facilitate effective asset management programs:

- Conduct an industry survey to identify and summarize key data elements, interfaces, components, and integrations for asset management including GIS and GIS-enabled applications, computerized maintenance management systems, hydraulic modeling systems, SCADA databases, customer information systems, and financial management systems.
- Assess state of the industry for systems integration and data management of leading asset management and IT solution providers.
- Develop candidate, standard data sets to improve and expedite asset management decisions. Identify alternative ways utilities could apply these standard data sets considering variations in utility size, services and structure.

Task 2. Convene an industry work group (consider collaborating with existing work groups working on similar efforts, such as the Water and Sewer Data Model) to establish systems integration approaches and a logical data model for asset management. Determine value, advantages and disadvantages, and appropriateness of each approach. This work group should consider the ongoing development and maintenance of the model, including identifying organizations to take on this responsibility.

Task 3. Develop a draft report of findings regarding integration approaches, logical data models, and IT integration best practices. Develop appropriate measures to address needs of utilities of various sizes.

Phase 2: Pilot Implementations

Task 4. Refine the integration approach and data model through pilot implementations at three utilities. Implement components of the integration approach and model at utilities and use outcomes and lessons learned to update the draft report and to prepare the final report.

Rationale:
Utility asset management is an integrated set of best practices and systems that achieve optimal and cost-effective investment and use of utility assets throughout their service life-cycle. The asset management model must be supported by systems integration and data models that demonstrate alternate ways to integrate component asset management systems and data. Currently there are several initiatives addressing specific elements and data models for utilities, but there is not an industry-specific initiative to develop an asset management integration and data model for the enterprise. The integration process and data model are needed to ensure that system interoperability truly supports an effective asset management program.

Benefits/Industry Value:

- Sets guidelines to assist utilities in understanding alternatives and applicability when determining a "best fit" solution for IT integration.
- Supports improved asset management decision making and reporting through the use of data sets and models that have been proven to work in operating utilities.
- Provides industry-standard integration and data model for use by vendors in software and product development. Over time, this will drive vendors to enable better integration and potential interoperability of component asset management systems.

Total Estimated Project Duration: Phase 1: 18 months, Phase 2: 24 months

Estimated Project Cost: Phase 1: $300,000 from AwwaRF. Phase 2: $250,000 from AwwaRF plus tailored collaboration matching funds – each utility participant should be willing to pilot primary elements of the integration approach and data model with a real dollar contribution of approximately $250,000 per utility piloted.

Research Area 5: Asset Management Information Technology and Data Management

Project 5.2: Evaluate Strategies for Data Creation, Collection, Validation, and Maintenance for Asset Management, including an Asset Data Dictionary

Project Description

Objective (s):

1. Based on international standards and best management practices, formulate standard procedures North American water/wastewater utilities should utilize to manage asset data.
2. Formulate guidelines for implementing asset data management procedures, practices, and technologies.
3. Create industry-standard, data dictionary templates for buried and aboveground assets. Templates will list critical asset data fields, recommend standard data field names, and identify an asset hierarchy that allows for relating work associated with assets.

Approach:

This project should be coordinated with ongoing AwwaRF funded research like "Data Requirements for Water Infrastructure Management" (AwwaRF In Progress); "Optimizing Information Technology Solutions for Water Utilities" (Red Oak Consulting In Progress); and the National Science Foundation's 5-year research grant to Virginia Tech to create SWIMS, Sustainable Water Infrastructure Management System (NSF 2007). In addition, the project should leverage international IT standards for data management and control – including data stewardship, metadata management, data security, data storage, data collection, data sharing, data visualization, and data revision control. The tasks to be accomplished include but are not limited to the following:

Phase 1

Task 1. Inventory and evaluate data creation, collection, validation and maintenance technologies that have been successfully deployed in North America and internationally. Technologies should include GPS-based devices, asset locators, condition assessment, equipment monitors, mobile computers, bar codes, radio frequency identification (RFID), data hubs, data warehouses, information portals, etc.

Task 2. Document best management practices and IT standards for data management, specifically those related to managing asset data. Evaluate data standards being used in various industries including water and wastewater, electric power utilities, oil and gas, automobile manufacture, and others.

Task 3. Survey utilities to determine the various data sets which are collected to facilitate asset management. Identify pending regulations and the anticipated data requirements of those regulations.

Task 4. Identify standards of practice relevant to water utilities for data management and control, including data stewardship, metadata management, data security, data traceability and audit, data storage, data collection, data sharing, data visualization, and data revision control.

Task 5. Develop a guidance manual for implementing data management procedures, practices, and technologies.

Phase 2

Task 6. Review existing data dictionary definitions used nationally and internationally to determine critical data sets being collected, typical data field naming conventions and standard asset hierarchy schemas.

Task 7. Develop asset data dictionary templates, critical asset data fields listing, and data field names. Work with software vendors to determine the best approach to bring the data dictionary schemas and supporting documentation to market.

Phase 3

Task 8. Conduct a pilot test to apply data management practices and data dictionary at participating utilities. Several utilities are currently embarking on projects that would benefit from this research. They should be approached to co-fund this initiative by piloting and testing the standards.

Rationale:
Currently there are no comprehensive industry standard practices, standard asset data dictionary templates or guidelines for creating, collecting, validating or maintaining water or wastewater data. Industry best management practices exist for data management, which can be applied to water asset management. The industry needs standard evaluation tools and suggestions to assist utilities in determining what data needs to be collected and how to use that data to support asset management decisions.

Benefits:
This project will:

- Improve data access, consistency, and accuracy for asset management decision making and strategies.
- Enable utilities to better determine what data to collect and how to use the data to support asset management.
- Assist utilities in turning data into information and knowledge to assist in their asset management decisions.
- Increase confidence in asset management decision making and reporting to regulatory and funding agencies.

Total Estimated Project Duration: Phase 1: 12 months, Phase 2: 12 months, Phase 3: 24 months

Total Estimated Project Cost: Phase 1: $150,000, Phase 2: $150,000, Phase 3: $250,000 from AwwaRF plus tailored collaboration, matching funds for participating utilities in Phase 3.

Research Area 6 – Operation and Maintenance Practices

Project 6.1: Guidance Document for Best Maintenance Practices for Water Distribution Assets

Project Description

Objective(s):
This project will not conduct new research but rather will gather and consolidate existing information. It will be a guidebook on maintenance practices, but because of the different types of devices and appurtenances, it cannot detail the specific practices for individual items or specific models. Such specific information can best be obtained from the supplier or manufacturer.

Specific objectives of this project are to:

1. Consolidate information and provide guidance on best maintenance practices for distribution system assets.
2. Develop preventative, predictive and corrective maintenance practices for water distribution assets (i.e., pipes, valves, pumps, finished water reservoirs, but not treatment plants).
3. Explore how maintenance practices relate to risk, criticality, life-cycle costs, condition assessment and related aspects of asset management.

Approach:
It will be important for this work to build on and coordinate with past and ongoing AwwaRF research such as "Criteria for Optimized Distribution Systems" (HDR Engineering, Inc. In Progress (b)); *Applicability of Reliability-Centered Maintenance in the Water Industry* (Basson et al. 2006), and materials already developed by the Water Services Association of Australia related to maintenance. Further, the products of this study should be updateable and should consider AWWA QualServe practices. The tasks to be accomplished include but are not limited to the following:

- Task 1. Conduct a review of literature, standards, and maintenance practices of distribution system assets, and prepare a summary White Paper.
- Task 2. Identify up to 10 asset classes for further review and definition.
- Task 3. Organize various work groups with utility practitioners and manufacturers/suppliers that are experts in maintenance of water distribution system assets. The purpose of forming work groups is to solicit information on good maintenance practices on each selected asset class and, where possible, gain consensus on appropriate maintenance approaches. The goal of each work group would be to identify good maintenance practices for various assets.
- Task 4. Based on the White Paper and work group outcomes, prepare a draft report which is distributed back to the work groups for review and comment.
- Task 5. Prepare a final report that incorporates comments and details good distribution system maintenance practices.

Note: Coordinate with Research Area 3, Project 3.2, Develop Guidance Manual for Condition Assessment of Water Main Appurtenances.

Rationale:
Distribution system assets represent a utility's largest capital investment. These assets include water mains, valves, hydrants, pressure-reducing valves and stations, pump stations, storage facilities, meters, backflow prevention devices, air release valves, and other appurtenances. Proper maintenance extends life and enhances operational characteristics. Currently, utilities rely on numerous sources of information and past practices to plan and carry out their maintenance programs. There is a need to review and consolidate practices into a single document or resource location to facilitate use by distribution system maintenance staff.

Benefits/Industry Value:
1. Provides a single location/resource for use by utilities where maintenance information has been consolidated and synthesized.
2. Provides clear linkage between maintenance and capital planning elements of asset management programs.
3. Enables utilities access to an independent source of best practices for maintenance of distribution assets.
4. Improves reliability, efficiency, productivity, cost-effectiveness, and service to the customers.
5. Contributes to cost containment by applying maintenance planning and cost-effective practices within a life-cycle asset framework.

Total Estimated Project Duration (months): 30 months

Estimated Project Cost ($): $400,000

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ABBREVIATIONS

AM	asset management
AMPLE	Asset Management Program Learning Environment
AMR	Automated Meter Reading
AMSA	Association of Metropolitan Sewerage Agencies
AMWA	Association of Metropolitan Water Agencies
AWWA	American Water Works Association
AwwaRF	Awwa Research Foundation
AWWU	Anchorage Water and Wastewater Utility
BAMI	Buried Asset Management Institute
CAD	computer-aided design
CAP	Condition Assessment Protocol
CARE-S	Computer Aided Rehabilitation of Sewer Networks
CARE-W	Computer Aided Rehabilitation of Water Systems
CCTV	closed-circuit television
CIM	Common Information Model
CIP	Capital Improvement Program
CIS	Customer Information System
CMMS	Computerized Maintenance Management System
CMOM	Capacity, Management, Operation & Maintenance
CSIR	Center for Sustainable Infrastructure Research
CSIRO	Commonwealth Science and Industrial Research Organisation (of Australia)
CWS	Charleston Water System
DCWASA	District of Columbia Water and Sewer Authority
DOTs	departments of transportation
DPU	Department of Public Utilities (Henrico County)
EAM	enterprise asset management (system)
EPRI	Electric Power Research Institute
FHWA	Federal Highway Administration
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Mode Effect and Critical Analysis
GASB	Governmental Accounting Standards Board
GIS	geographic information system
GTI	Gas Technology Institute
GWRC	Global Water Research Coalition
I&I	inflow and infiltration
IPWEA	Institute of Public Works Engineering Australia
ISO	International Standards Organization
IT	Information Technology
IWA	International Water Association
Kiwa	Kiwa Water Research
KPIs	key performance indicators
LADWP	Los Angeles Department of Water and Power
LBWD	Long Beach Water Department
LCC	life-cycle cost

LIMS	laboratory information management system
LWC	Louisville Water Company
MGD	million gallons per day
MRO	maintenance, repair, and overhaul
MRRP	Main Replacement and Rehabilitation Program
MRRR	maintenance, repair, rehabilitation, and replacement
MWRA	Massachusetts Water Resources Authority
NACWA	National Association of Clean Water Agencies
N.d.	no date
NRC	National Research Council (of Canada)
NSF	National Science Foundation
NWC	National Water Commission (Australia)
NWI	National Water Initiative
O&M	operation and maintenance
PAC	Project Advisory Committee
PCCP	pre-stressed concrete cylinder pipe
PM	preventive maintenance
PRVs	pressure-reducing valves
R&R	replacement and renewal
RAC	Research Advisory Council
RCFA	Root Cause Failure Analysis
RCM	Reliability-Centered Maintenance
RFP	Request for Proposal
SAM	Strategic Asset Management
SCADA	System Control and Data Acquisition
SIMPLE	Sustainable Infrastructure Management Planning and Learning Environment
SPU	Seattle Public Utilities
SWIMS	Sustainable Water Infrastructure Management System
TPM	Total Productive Maintenance
UKWIR	United Kingdom Water Industry Research Limited
USDOT	United States Department of Transportation
USEPA	United States Environmental Protection Agency
USGAO	US General Accounting Office
WEF	Water Environment Federation
WERF	Water Environment Research Foundation
WRc	WRc Group UK
WRF	Water Reclamation Facility
WSAA	Water Services Association Australia
WTF	Water Treatment Facility

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