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November 7, 2018

Proposal for Engineering Services

PRESTRESSED CONCRETE CYLINDER PIPE (PCCP) CONDITION ASSESSMENT

SAINT PAUL REGIONAL WATER SERVICES
SAINT PAUL, MINNESOTA

AECOM
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November 7, 2018

Mr. Paul Dotson
Buyer
Department of Human Rights & Equal Economic Opportunity
15 West Kellogg Boulevard
Saint Paul, MN 55102

Subject: **Request for Proposals for Engineering Services**
Prestressed Concrete Cylinder Pipe (PCCP) Condition Assessment
Saint Paul Regional Water Services
Add. #1 - 10/4/18 | Add. #2 - 10/11/18 | Add. # 3 - 10/17/18 | Add. #4 - 10/31/18

Dear Mr. Dotson:

Saint Paul Regional Water Services (SPRWS) is relied upon to provide safe, quality water to the City of Saint Paul and neighboring communities. This Prestressed Concrete Cylinder Pipe (PCCP) Condition Assessment is an important piece of the Master Plan to provide 50+ more years of reliable service.

This PCCP Condition Assessment will assist the SPRWS Board in determining the actual condition of previously installed PCCP. This assessment will also assist in predicting future failures.

AECOM has been a leader in condition assessment of aging infrastructure for decades. We have authored and presented numerous papers on this topic. Recently, AECOM presented two papers on PCCP Condition Assessment projects at the ASCE 2018 Pipelines Conference in Toronto. See Appendix B for copies of those papers. AECOM was acknowledged by ASCE in 2012 with the *Stephen D. Bechtel Pipeline Engineering Award*. SPRWS will benefit from our top experts in this field, including ***Chris Macey, Marshall Gibbons, Tom Degen, Mike Winegard, Andrew Romer, Robert Vail*** and ***James Jameison***. Our National Practice Leader for Condition Assessment and Rehabilitation, Chris Macey, has 40 years of experience and has authored and instructed numerous Best Practices courses across North America on condition assessment and rehabilitation. Our proposed team has successfully completed many major critical condition assessments very similar to your scope for the PCCP Condition Assessment for many clients across the country and around the world.

Our team is very familiar with SPRWS staff and facilities through our work with the Raw Water Conduit Assessment Project and the PCCP Prioritization Study and Technical Memorandum. ***Tom Degen***, who provided Project Manager services on the buried asset management and condition assessment projects for SPRWS, will provide technical assistance on this project. ***John Lapointe*** has worked on similar infrastructure evaluation projects and can provide immediate responsive service from the Minneapolis office.

AECOM has the resources, approach and experience to successfully complete this project on time and within your budget. Leadership from our technical experts will streamline the process and allow efficient project delivery. AECOM will work with SPRWS staff to ensure a clear road map that all team members will follow.

Further, AECOM is uniquely offering to transfer key aspects of their Condition Assessment knowledge to designated SPRWS staff through this program by offering training in conducting Stage I through Stage III Condition Assessment techniques for PCCP. In this manner, SPRWS can become self-sufficient over time in assessing and maintaining the integrity of this critical water transmission asset. Messrs. Macey and Gibbons are both not only experienced practitioners in the art of condition assessment, but in training as well. AECOM has very successfully transferred knowledge and established long-term collaboration partnerships in this manner in active programs with CSU Utilities in Colorado Springs, Colorado, and with SFPUC in San Francisco, California's, assessment programs.

We are excited to work with SPRWS on this project. All proposed team members are available to dedicate the required time necessary to begin this project upon approval and complete within your schedule. We look forward to working with SPRWS and continuing our discussion on this important PCCP Condition Assessment project.

Sincerely,

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1 PROPOSER'S UNDERSTANDING, APPROACH AND WORK PLAN

BACKGROUND

Saint Paul Regional Water Services (SPRWS) has approximately 48.4 miles of prestressed concrete cylinder pipe (PCCP) inventory in its existing distribution system. The system is comprised of pipe sizes ranging in diameter from 16 inches to 90 inches and ages ranging from circa 1952 to 2001. In December of 2017, AECOM completed a risk-based initial screening assessment for the PCCP inventory to facilitate prioritization of a formal condition assessment program.

Based on the AECOM report, the initial focus was intended to be on the 1.2 percent length segment of the inventory highlighted in Table 1 below as having the highest Risk Category (red) and the 19.4 percent length segment of the inventory having the next highest Risk Category (orange).

Category	Consequence of Failure	Probability of Failure	Length	Percentage of Length
Red	High	High	0.6 miles	1.2 percent
Orange	High/Moderate	High/Moderate	9.4 miles	19.4 percent
Yellow	Moderate	Moderate	16.8 miles	34.9 percent
Green	High/Moderate	Low	4.5 miles	9.4 percent
Light Green	Low	Moderate/Low	14.4 miles	29.8 percent
Light Blue	Low	High	2.6 miles	5.3 percent

Table 1: Risk Categorization of PCCP Inventory

As the higher end of condition assessment tools require a considerable investment of funds and are not without their own risk to deploy, it was recommended to initiate a pilot program with more advanced screening to gain a better understanding of:

- Areas that have the highest priority for the deployment of advanced tools,
- The specific tools that would be recommended for each area based on a balance of risk and site logistics, and
- A logical timing that would be prudent for the program that is commensurate with the risk that is determined in the pilot program.

Specifically, the following work items were identified as a logical program for the pilot works:

a. A detailed load assessment based on the design and shop drawings in all instances where this information is present to determine the actual operating points (i.e., internal pressures and external load) for the pipe sections versus the original limit states (e.g., the maximum combination of pressures and external loads that the pipes could accommodate based on the original design). This will establish original factors of safety for large sections of the inventory which are known to be highly variable and will provide valuable insight into pipes that could accommodate a great deal of deterioration versus pipe where very little deterioration could be accommodated.

In instances where no design information is available, utilize a strategic portion of the field program as noted below to better quantify material type, exposure conditions (e.g., depth of bury and corrosion potential).

b. A field investigation program to better categorize external exposure conditions of representative segments in the High and High/Moderate Risk Categories (shaded red and orange above) to specifically highlight:

I. Soil chemistry and electrochemistry characterization to confirm vulnerability to ferrous metal and cementitious material break down.

II. Actual external loading cases (e.g., loads due to depth of bury, etc.).

III. Office review and surface reconnaissance to highlight any other deterioration risk factors such as stray current corrosion possibly resulting from impressed current cathodic protection systems associated with adjacent utilities (e.g., natural gas, electrical, etc.) or other possible stray current sources (e.g., trains, light rail, etc.).

c. A detailed site investigation program to expose pipes at targeted specific locations where a combination of lower original factors of safety and higher deterioration potential exists.

d. Quantification of pipe condition discretely at these locations, re-categorize inferred condition (i.e., recalculate the factor of safety based on newly acquired data) to actual condition, extrapolate the results to the remaining segments based on the external exposure assessment above and rationalize the need for, and timing of, more advanced condition assessment on the segment.

e. The specific inspection outcome of this approach could be:

I. Probability of failure may be downgraded to the point that no further assessment is needed.

II. The inferred probability of failure may be confirmed, with specific recommendations on the most appropriate assessment technique and supporting information to provide the template to carry out the work.

III. The pipe segment may be found to be in such a poor state that emergency or short term repairs may be recommended.

As a result of the pilot program field investigations, SPRWS would like the following output from the program:

- An estimate of an appropriate annual budget that should be dedicated to additional condition assessment utilizing advanced non-destructive testing methods for the highest risk categories (red and orange) of PCCP.
- An estimate of the most appropriate timing for future analysis on portions of the inventory in each of the remaining Risk Categories.

Our Work Program to fully achieve these objectives is detailed in the following sections of the proposal. Further, as an added value to the Work Program, AECOM offers to train designated SPRWS Technical Staff in the techniques of Stage I through Stage III Condition Assessment for PCCP by participating in the field program and formal training. This service would be provided as an added value service at no additional cost.

1.1 Project Management and Kickoff Meeting

Project Scope/Change Management.

AECOM's Project Manager will use our company-wide ePM (Project Management) tool to assist in maintaining project timelines and budgets. ePM incorporates integrated, leading-edge and user-friendly financial and project management tools that will provide our Project Manager with instantaneous on-site access to project financial information. ePM provides immediate feedback on the current expenditures related to budget targets. Corrective action can be taken any time a problem is suspected or identified.

Our Project Manager will also maintain close contact with the Project Team involved in order to keep the project in line with the proposed scope of work, schedule and budget. In addition, AECOM senior personnel will review all work for conformance with project requirements and quality.

ePM provides actual time and expense cost for individual members of the Consultant Project Team involved in each phase of the project, and highlights a comparison of actual totals to budget targets. The progress of accumulated actual total expenditures compared to budgets can be closely monitored. Each phase of the work in progress is subjected to review by the AECOM Project Manager to provide reasonable correlation between actual progresses of the work with the budget expended. Anticipated progress and time expenditure is plotted at the outset of the work to define the objective. The weekly cost control information described above is superimposed on this objective as is the estimated progress realized.

These procedures identify very quickly the fact that either the objectives are being met, or that a variance has occurred. Sufficient data is also available to identify the discipline in which the variance is occurring. The speed with which any variance from the objective can be identified permits remedial action to be taken by the Project Manager to regain control over the correlation between the expenditures and actual progress prior to budgets being depleted.

Schedule Management.

AECOM fully appreciates that project administrative services are a critical aspect in delivering a successful project on time. Our project team has experience administering contracts for a wide variety of projects requiring diverse and multi-disciplinary project teams.

The two main facets of project administration are cost and schedule.

We recognize that time is critical for this project and that requests must be addressed quickly. We are committed to working with SPRWS to prevent delays in carrying out the work.

Quality Management.

AECOM offers a proven Quality Management System (QMS) that is certified to the international ISO 9001:2008 standard, yet sufficiently flexible to address the specific requirements of this project. Quality Control and Quality Assurance are central to our project management approach, and our project team includes individuals assigned to specific quality review roles. The general components of AECOM's approach to project quality management, and the parties responsible for them, are described below.

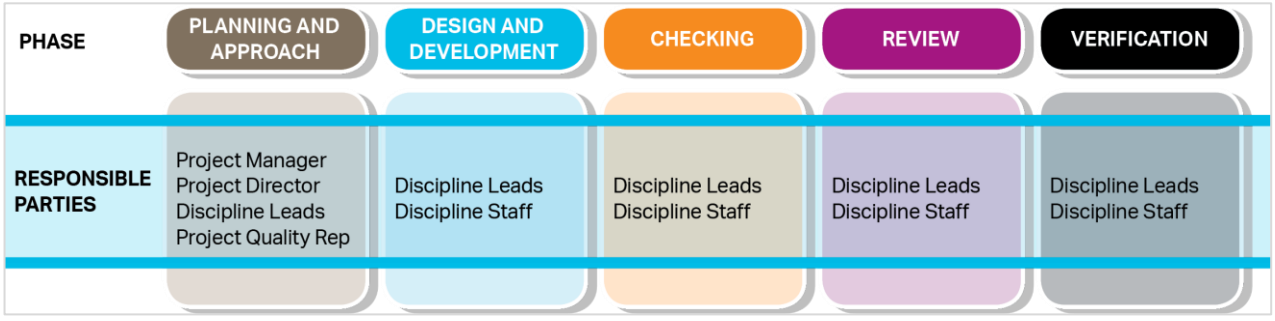
Initiating Quality.

Quality begins with AECOM's understanding of your project goals and objectives, emphasizing communication with the City, and a thorough review of project inputs. Assigning technically qualified and experienced personnel to produce and to review the work is an important next step. Our initial planning and scheduling activities, including defining the various project work tasks and associated quality activities, are the foundation of a successful project.

Producing Quality.

AECOM requires an internal Project Plan on all projects to define key parameters and to guide the work of the Project Team. The Plan is discussed at the Project Team Kickoff Meeting and updated, as needed, to inform the team of new developments. As work proceeds, a number of critical technical activities are undertaken, including:

- Proper application of regulations, codes, standards, and design criteria;
- Ongoing oversight and supervision for accuracy and completeness of work;
- Distribution of in-progress documents at defined intervals for quality review;
- Verification of compatibility and consistency among document types, such as drawings and reports;
- Resolution and closure of in-progress review comments; and
- Confirming quality.



While it is important to build quality into the work as it is performed, formal checking and review are critical QMS activities. Quality checking activities, which are all documented, include:

- Checking calculations to verify correctness and completeness of mathematics, methodology, application of regulations, standards and codes, and general approach.
- Checking drawings to confirm layout, dimensions and details. Potential interferences, conflicts and interface issues are resolved through interdisciplinary reviews.
- Checking specifications for content and application, as well as compliance with the prescribed format, and for consistency throughout the specifications.
- Checking studies/reports for content, logic, clarity and soundness of recommendations, as well as grammar, punctuation and format.

DELIVERING QUALITY. All deliverables undergo a final verification check before they are submitted. An Independent Reviewer evaluates the deliverable for completeness and consistency, adherence to quality requirements, and resolution of comments. The reviewer then signs an internal Deliverable Release Form and transmits it to our Project Manager, who is then responsible for the final approval and submittal. The draft version of reports will be submitted to SPRWS for review and comments prior to finalization.

This final independent evaluation assesses the submittal's state of readiness, without diminishing the Project Manager's accountability for the quality of the work being released. Client input into the Work Plan is welcome and will be obtained through the cooperative client review of draft documents. It is assumed that SPRWS staff will provide one set of coordinated comments to the Project Team on the provided deliverables. We will then revise, as required, draft documents to reflect these comments.

IMPROVING QUALITY. A key component of AECOM's quality program and ISO 9001 is continuous improvement. We learn from our experiences and apply those lessons to future work through a formal, iterative process. The true focus of this process is to generate client satisfaction, one of AECOM's Core Values.

COMMUNICATION MANAGEMENT. Communication is a key factor in the success of any project. The AECOM Project Manager's primary focus will be communication with SPRWS's Project Manager. At project inception, the AECOM Project Manager will establish a communication plan which will be closely monitored and adjusted, as necessary, for open, collaborative and concise communication over the life of the project.

The method of communication will vary between phone calls, e-mail and written work plans/scope changes. Other methods of communication that are likely to be employed are conference calls and face-to-face meetings. The method of communication will be chosen based on its efficacy in keeping our AECOM team and client team informed and involved. For budgeting purposes, AECOM has provided for interaction between SPRWS and AECOM as follows:

- Project Kick-Off Meeting – In Person – Discuss Work Plan and Schedule
- Monthly Project Status Reports
- Final Presentation of Results Identified in the Summary Report

As noted in the RFP, the purpose of the Kick-Off Meeting will be to build stakeholder consensus on the project mission, identify critical success factors, discuss the consultant's proposed pilot program implementation, review inventory information, discuss project communication procedures and schedule, and determine ownership responsibility for execution of the developed action plans.

Task 1 Deliverables will include:

- Kick-Off Meeting Minutes
- Project Schedule and Monthly Updates
- Monthly Status Reports
- Final Presentation of Results

1.2 TASK 2 - IMPLEMENT PILOT PROGRAM OF HIGH/MODERATE AND HIGH RISK CATEGORIES INVENTORY

Task 2 includes three distinct sub-tasks:

- Detailed Loading Assessment
- Field Investigations – Initial Screening
- Field Excavation and Sampling Program

A description of each sub-task follows.

1.2.1 Detailed Loading Assessment: Despite a good performance history to date with PCCP feeder mains, given the age of the network, a greater understanding of the risks associated with the pipelines will allow for the deployment of a targeted condition assessment program intended to quantify the physical condition of the network as a whole. This process will begin with developing an applied loads/deterioration model for all PCCP pipes that have laying schedules and original design information utilizing an MS Access Database application developed in-house by AECOM's Winnipeg team to assess large pipe networks. This model has been successfully applied to assess entire water main networks in Toronto, ON; Colorado Springs, CO; Regina, SK; and Detroit, MI; and large force main networks in Virginia Beach, VA; San Francisco, CA; Ottawa, ON; and Raleigh, NC.

The model will be built using existing GIS data, AECOM's unique knowledge of the network based on the original study carried out, and record information provided by SPRWS. The load model will further utilize internal pressure data provided by SPRWS to assess the factor of safety against failure on a discretized feeder main network (largely using valve-to-valve segmentation of the system). Overlying the results of the load model with deterioration risks will allow the identification of pipelines with a higher failure potential.

The primary focus of the task is development of an applied loads and deterioration model encompassing both internal pressures and external soil and live loads applied to the pipelines in question, as well as known deterioration drivers. Development of this model will require input from SPRWS in terms of the system operating pressures as described below. Generalized assumptions on soil covers and pipe strengths to facilitate completion of the scope of work within the City's identified budget will also be required. Known deterioration drivers, such as elevated chloride levels, will also be factored into the model based on major street buffers developed in the December 2017 study and then refined based on the field program in Task 2.2.

As described above, AECOM will utilize an MS Access Database application developed in-house for analyzing large pipe networks, see Figure 3. This approach provides greater insight into failure timelines than studying deterioration rates alone as the factors that govern failure relate to the unique applied load in each pipe segment. Considerable research into applied loads indicates they vary widely across large networks based on variations in the pressure grid.

AECOM Development of the load model will involve the following and follow the process shown in Figure 1:

- Developing a GIS dataset for the PCCP network. Our model will utilize existing GIS data, modified to represent a discretized pipe network suitable for network prioritization.
- Update GIS dataset/load model to reflect the structural capacity of the PCCP pipelines:
  - The unique nature of PCCP results in pipe classes and associated load carrying capacities that can vary from year to year and manufacturer to manufacturer. Further, pipe classes can change along the length of the pipeline to reflect changes in loading conditions. To properly model PCCP pipelines in the load model, AECOM will pull load-carrying capacity from the original pipe design records, where available. Based on the December 2017 study, SPRWS had accumulated a considerable number of relevant design records.
  - Only PCCP materials will be analyzed in the model.
- Update ground elevations in the GIS dataset using the best available LIDAR survey information.

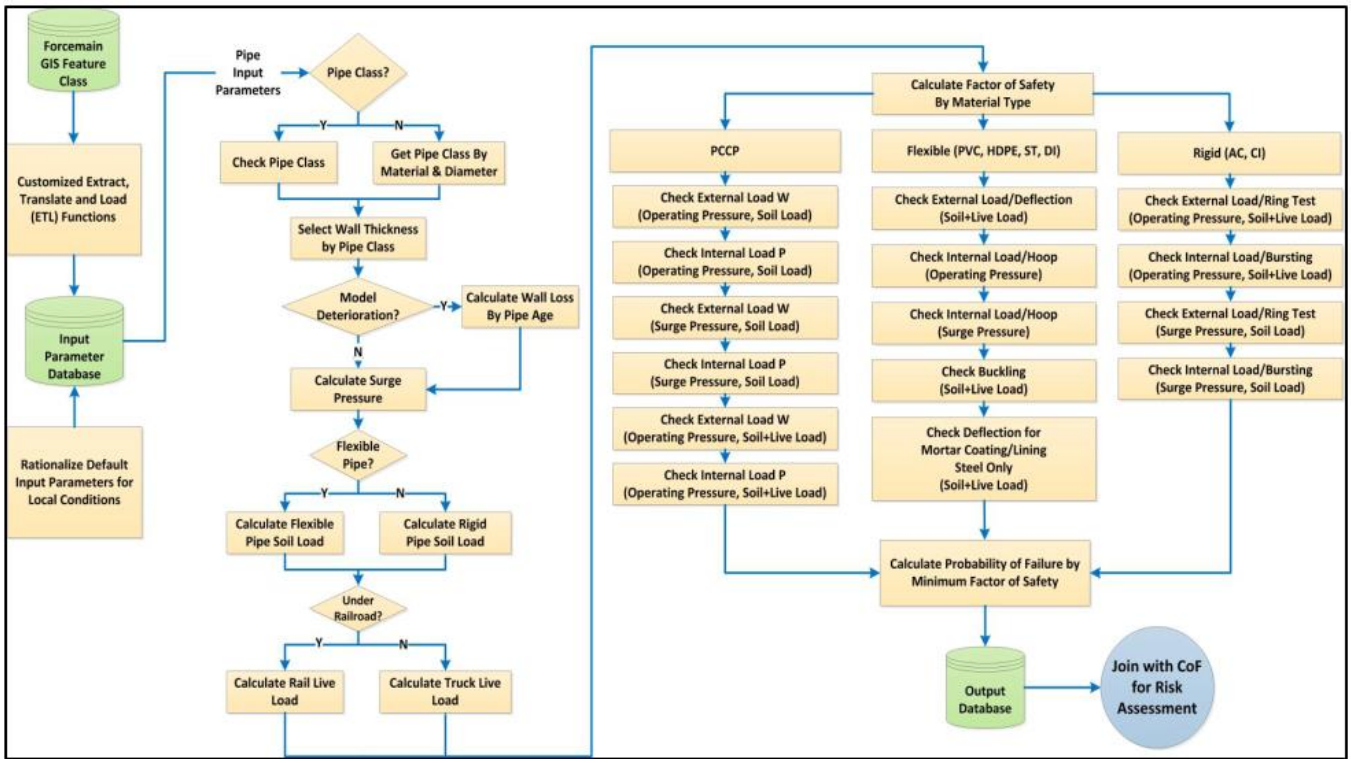


Figure 1: Applied Load and Initial Screening Flow Chart

- Update the GIS dataset/load model to reflect external loading conditions of the pipe inventory:
  - Only PCCP materials will be analyzed in the model.
  - Invert depths will be set to a standard depth across the entire inventory to reasonably represent the inventory. Identifying pipe invert depths on a discretized basis is not feasible within the identified project budget, but individual sites will be updated based on available GIS information and at the site specific excavation sites.
  - Applied live loads will be estimated using standard design vehicles (AASHTO HS20) or rail loads as applicable.
- Update the GIS dataset with internal system pressures:
  - SPRWS has a model of the PCCP network at an adequate discretization level. Our scope of work is based on SPRWS providing an HGL map for the system under normal operating conditions in a GIS compatible format.

In AECOM work assignments in Colorado Springs, CO[1], an innovative technique was developed to integrate the output of the hydraulic model with a digital terrain model (DTM) using raster imagery and a raster mathematics technique to uniquely assign normal pressure rating attributes discretely to each unique pipe segment in a 220,000 segment network (Figure 2). This greatly enhanced the feasibility of the widespread application of a deterministic approach to predict failure and residual pipe life to an entire system.

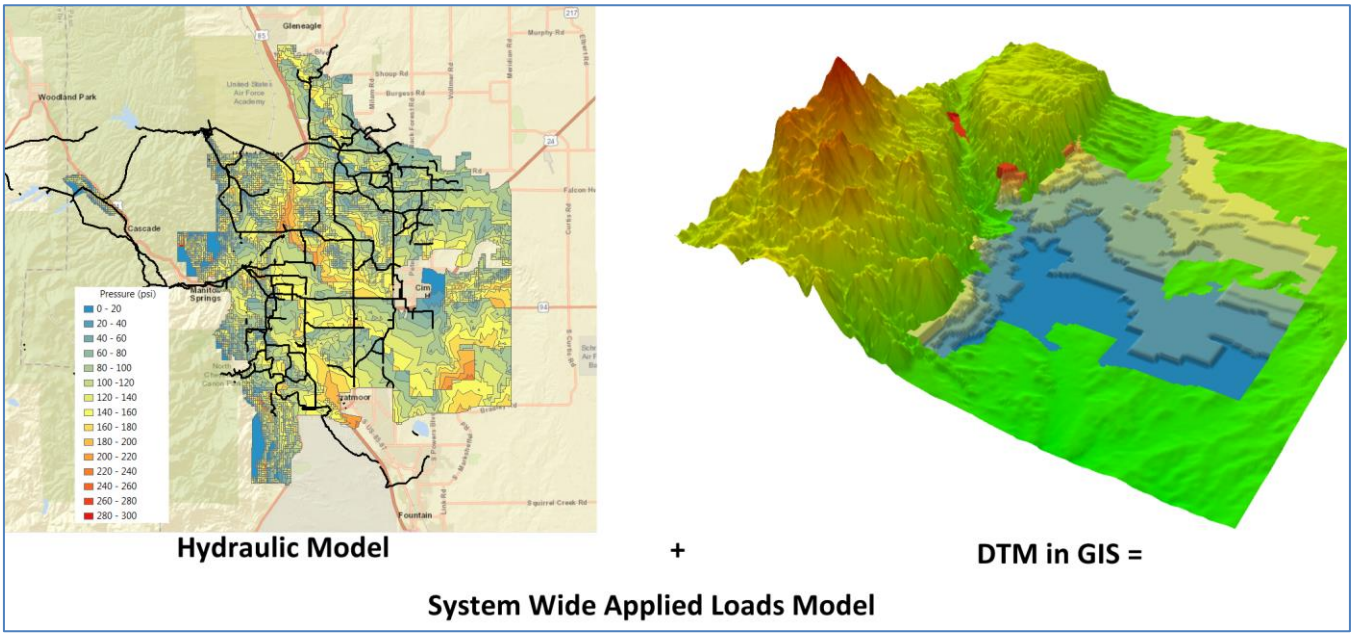


Figure 2: Integrating a Hydraulic Model with a DTM

[1] Macey, Davidson, Croft et al, "Risk Based Condition Assessment and Rehabilitation Planning In Colorado Springs". ASCE Pipelines Proceedings, August 2014

The result of the above analysis will be a factor of safety against failure for both external loading and internal pressure which will be utilized to highlight pipelines at risk of failure.

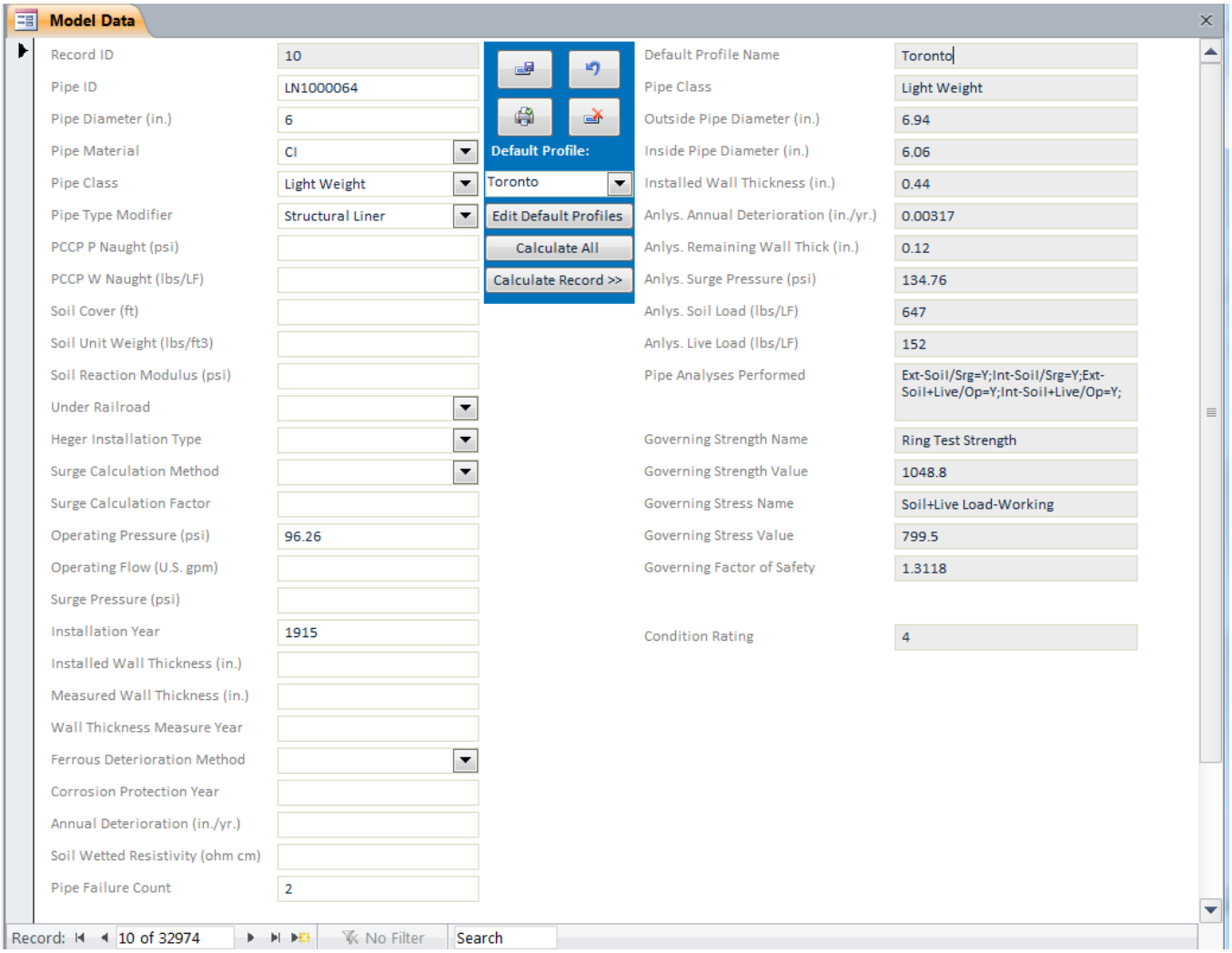


Figure 3: AECOM's Pipeline Load Assessment Application

1.2.2 Task 2.2 – Initial Field Investigation Program:

The initial field investigation program will better categorize external exposure conditions of representative segments of all High and High/Moderate Risk Categories to specifically highlight:

- Soil chemistry and electrochemistry characterization to confirm vulnerability to ferrous metal and cementitious material break down.
- Office review and surface reconnaissance to highlight any other deterioration risk factors such as stray current corrosion possibly resulting from impressed current cathodic protection systems associated with adjacent utilities (e.g., natural gas, electrical, etc.) or other possible stray current sources (e.g., trains, etc.).

The initial field survey to directly measure electrochemistry and infer critical chemistry characteristics will be carried out using a Multi-Frequency EM Conductivity Meter - Profiler™ EMP 400, as depicted in Figure 2 below.

Figure 2: Profiler™ EMP-400

The Profiler™ EMP-400 uses geophysics to ascertain critical electrochemistry properties that highlight differing levels of corrosion risk and, by inference, the likelihood of elevated chloride levels when increased conductivity levels are measured in close proximity to high surficial chloride locations (i.e., busy streets).

In review of the majority of the high, high/moderate and moderate risk locations, it was observed that the majority are through residential or "rural" highway areas and should be fairly accessible. The downtown and main routes radiating from there are wall-to-wall concrete so they may not be feasible to survey without extensive traffic control. There are several highway interchanges or overpass crossings that may be difficult to negotiate, but surveys can extend right up to these locations to capture areas where chlorides are typically elevated. There are also a few railway crossings; however, they should be able to be surveyed on each side as opposed to through the

railway ROW. AECOM will supply a two-man crew to facilitate inspections. Due to the uncertainty of the exact routes of the surface reconnaissance work (using the Multi-Frequency EM Conductivity Meter) and subsequent excavations to expose sections of PCCP, Traffic Control Services are NOT included in the scope of this proposal. Traffic Control Services will be evaluated and discussed with SPRWS prior to initiating the pilot program and added to the scope as needed.

With the exception of the site-specific constraints noted above, we envisage all high and high/moderate locations can be surveyed.

The combined results of Tasks 2.1 and 2.2 will be used to target specific locations for detailed assessment by excavation.

1.2.3 Task 2.3 – Field Excavation and Sampling Program. Based on the results of Tasks 2.1 and 2.2, it is estimated that between 5 and 10 sites will be selected for detailed excavation. As per Addendum #3, the SPRWS Operations Crews would conduct the excavations and site restorations, with the costs tracked within the overall project limit, and AECOM would supply an NACE certified field technician (Marshall Gibbons) to conduct the visual and NDT assessments. The targeted locations will be locations where a combination of lower original factors of safety and higher deterioration potential exists.

The work will include:

- Quantification of pipe condition discretely at these locations by:
  - Visual classification using a balance of NACE- and ACI-accepted classification criteria.
  - Pipe-to-soil potential survey locally to ascertain whether there is any active corrosion processes present on the prestressing wires.
  - Characterization of the soil and groundwater environment around the pipe by a balance of in-place and laboratory testing to confirm:
    - Soil Resistivity
    - pH
    - Redox Potential
    - Sulfide Presence
    - Sulphate Concentrations
    - Chloride Concentrations
- Re-categorization of the inferred condition (i.e., recalculate the factor of safety based on newly acquired data) to actual condition,
- Extrapolation of the results to the remaining segments based on the external exposure assessment above, and
- Rationalization of the need for timing and methodologies required for more advanced condition assessment on the segment.

Task 2 Deliverables will include:

- Spatially rectified conductivity survey results in a shape file.
- Loading assessments to the extents possible by available records and the observed site conditions. Loading assessments will be delivered in two forms: output from the detailed assessments and a shape file that would facilitate upgrading condition in SPRWS's GIS for PCCP pipe elements.
- Detailed assessment of condition for each specific excavation location based on the supplementary data collected in those investigations.

1.3 TASK 3 - REPORTING

Task 3 includes the following sub-tasks:

- SPRWS Workshop to Review the Results of the Pilot Program
- Rationalization of Advanced Condition Assessment Requirements
- Future PCCP Condition Assessment Scheduling
- Preparation of Draft and Final Reports

As a result of the detailed excavations, each site (and associated segments) will be assessed as to whether:

- The probability of failure may be downgraded to the point that no further assessment is needed.
- The inferred probability of failure may be confirmed and a more advanced assessment could be identified as a follow-up activity with specific recommendations on the most appropriate assessment technique and supporting information to provide the business case to carry out the work.
- The pipe segment may be found to be in such poor condition, such that emergency or short-term repairs may be recommended.

As a result of the pilot program overall, the following information will be provided:

- An estimate of an appropriate annual budget that should be dedicated to additional condition assessment utilizing advanced non-destructive testing methods for the highest risk categories (red and orange) of PCCP.
- An estimate of the most appropriate timing for future analysis on portions of the inventory in each of the remaining Risk Categories.

Task 3 Deliverables will include:

- Meeting with SPRWS to review results of pilot program and updated risk analysis.
- Specific recommendations on the appropriate assessment techniques and methods to carry out future assessments.
- Estimate of annual budget dedicated to advanced non-destructive condition assessment of the highest risk (red and orange) PCCP assets.
- Estimate of the most appropriate timing for future analysis on portions of the inventory in each of the remaining Risk Categories.
- Should SPRWS desire to designate key personnel for training in Stage I through Stage III PCCP assessment techniques, the Workshop Deliverables will also include a formal training session on the techniques and tools utilized on the assessments. SPRWS may enable them-selves to extend the screening to the remaining inventory with outside technical support but a greater proportion of in-house resources. AECOM has successfully deployed this style of training in large scale Condition Assessment Programs in Colorado Springs, Colorado, and for SFPUC in San Francisco, California.

2 Previous Work Providing Similar Services

Raw Water Conduit Assessment

St. Paul Regional Water Services

Client
SPRWS

Total Project Cost
$369,000

Contact
Rich Hibbard
Project Manager
1900 Rice Street
Saint Paul, MN
651.266.6268

Saint Paul Regional Water Services (SPRWS) supplies drinking water to nearly 435,000 customers in the City of Saint Paul and neighboring communities, averaging 40 million gallons per day (MGD). The primary source for this water is the Mississippi River at Fridley, where an Intake Pumping Station with a capacity of 90 MGD pumps water into two parallel 60-inch conduits (Mississippi Conduits #1 and #2) that convey the water eastward 8 miles to Charlie Lake, which flows into Pleasant Lake. Flow continues southward by gravity via two 0.5-mile, parallel 60-inch conduits (Pleasant Conduits #1 and #2) to Sucker Creek and Sucker Lake, which flows into Vadnais Lake. In the final leg, water from Vadnais Lake, supplemented with water extracted from up to five groundwater wells along the route, is conveyed by gravity to the McCarrons Water Treatment Plant via two 4.4-mile, 90-inch conduits (Vadnais Conduits #1 and #2).

Aside from visual observations of the interior of the conduits during past maintenance and repair programs, no rigorous physical condition assessments of the conduits have been completed. Portions of some conduits reportedly have never even been inspected. The oldest of the conduits was constructed in 1924.

AECOM was retained by Saint Paul Regional Water Services to complete full-length inspections and evaluate the physical condition of all six raw water conduits, including the identification of any required remedial works. Aside from the raw water lines, AECOM was also required to review all prestressed concrete cylinder pipe (PCCP) in potable water transmission service, assess risk in a desktop screening assessment, and develop a prioritization program for more advanced condition assessment studies.

The primary objectives of this project were to obtain an assessment of the raw water supply conduit system, including an evaluation of its structural and hydrostatic integrity, to identify any immediate repair requirements and a prioritized, staged improvement program to reliably sustain the asset and extend its useful service life a minimum of another 50 years.

Key aspects of these overall objectives included the need to:

- Develop a clear understanding of the current condition of the conduits; of the nature, severity and spatial distribution of their defects.
- Identify factors that led to the defects occurring and future deterioration risks for the supply lines in their present state with current operation and maintenance protocols in place.
- Provide an assessment of the effectiveness of past and current repair methodologies and their anticipated design life.
- Establish performance/service criteria as a benchmark to quantify acceptable condition and service level objectives moving forward.
- Conduct an assessment of residual life and anticipated service level degradation without intervention.
- Develop an optimized rehabilitation program to meet the defined performance service objectives.
- Identify any further investigations that may be warranted to more precisely define condition, remaining service life, and anticipated upgrading requirements.

A two-stage inspection program was conducted to observe conduit condition and acquire data needed to facilitate office assessment studies:

- Stage 1 included a section-by-section inspection recorded with hand-held CCTV inspection equipment.
- Stage 2 included a detailed pipe segment-by-pipe segment assessment.

Based on the data accumulated from the field inspections, AECOM conducted office studies to:

a. Assess the condition of the pipe and confirm the primary deterioration mechanisms that are responsible for the observed condition and need to be considered to assess failure risk and residual life moving forward.

b. Ascertain where it may be prudent to acquire additional information to increase the knowledge of condition, deterioration processes and remedial requirements.

c. Assess residual life in areas where deterioration has occurred or active deterioration processes are present.

d. Develop a prioritized, comprehensive maintenance and rehabilitation program to extend the life of the raw water supply asset for a minimum of another 50 years.

NORTH FORK SIPHON REPLACEMENT PROJECT

CENTRAL UTAH WATER CONSERVANCY DISTRICT, HANNA, UT

Following AECOM's completion of Phase 1 (initial contract) of the project (inspection and condition assessment for existing North Fork), AECOM designed the North Fork Siphon Replacement project for the Central Utah Water Conservancy District. When constructed, the North Fork Siphon Replacement will be an approximately 4,800-foot long, 84-inch diameter steel water line, traversing steep slopes into and out of a channel valley, while covering a 716-foot vertical elevation change from inlet to the valley floor on an approximately 70 degree slope. As part of the preliminary design, AECOM conducted a pipeline alignment analysis. In this process, AECOM accounted for wetlands, geology, slope characteristics, and existing utilities in determining the preferred pipeline alignment. Following selection of the preferred pipeline alignment, AECOM conducted the geotechnical investigation to confirm subsurface conditions outlined in the original project and identified potential geohazards.

Client
Central Utah Water Conservancy District (CUWCD)

Total Project Cost
$1,128,000

Contact
Blake Buehler
CUWCD
355 West University Parkway
Orem, UT
CUWCD
801.226.7133

After developing potential alignments through a collaborative effort with the District, AECOM investigated alignments to determine features that would impact cost, longevity, and impact. The identified features and impacts, as well as AECOM's recommendation, was presented to the District. The collaborative process led to selection of a pipeline alignment that will ensure long-life and minimize environmental impacts.

Additionally, during the preliminary stages of the design, AECOM presented a pipe material and joint selection, which was a new approach for the District. Through joint discussion of alternative pipe materials and joint options, the District and AECOM agreed to proceed to investigation of the selections with the intent of proceeding with these options. It is expected that the material and joint type will promote the longevity of the pipeline, while also reducing project costs.

PCCP Failure Risk Analysis

Tampa Bay, FL

Client
City of Tampa Bay Water

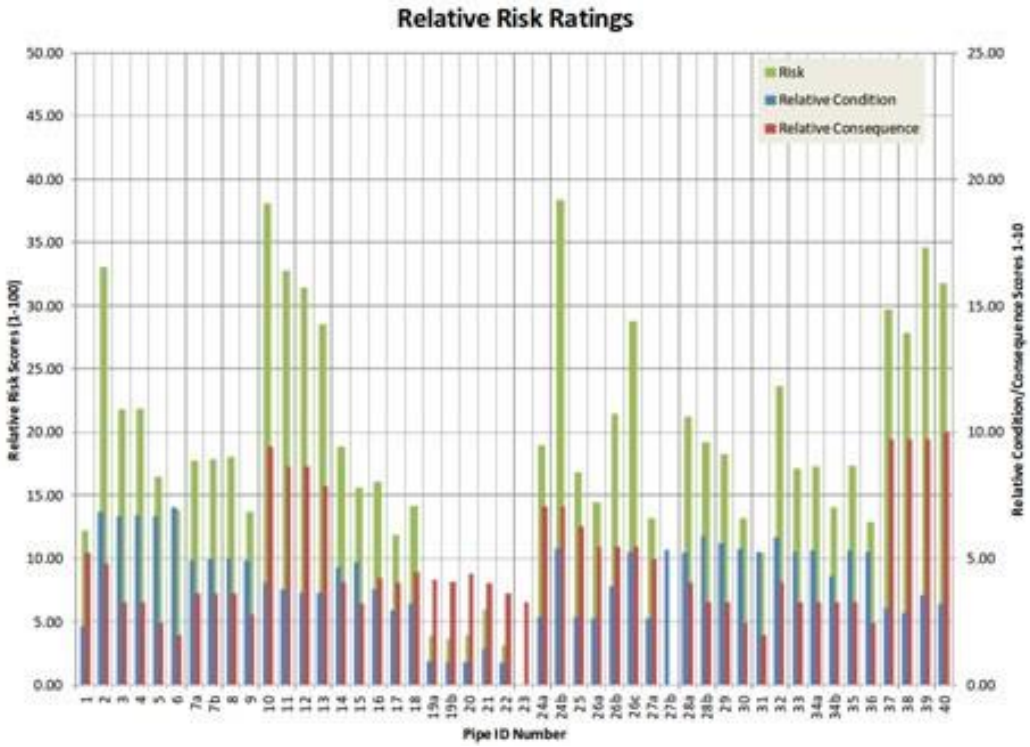
Total Project Cost
$50,000

Contact
Suzannah J. Folsom, PE
2575 Enterprise Road
Clearwater, FL
Tampa Bay Water
727.669.4817

Within the Tampa Bay Water (TBW) water transmission system, there are approximately 40 to 50 PCCP segments totaling between 100 miles to 150 miles in length. Internal diameters for these PCCP segments range from 30 inches to 96 inches. These PCCP segments typically convey raw water or potable water. Several catastrophic failures of PCCP piping had occurred in this system. The inventory includes significant quantities of Interpace pipe that was manufactured with Class IV prestressing wire. This pipe is known to have a considerable failure history across the US market.

TBW desired to proactively evaluate the existing PCCP piping and prevent catastrophic failures. The cost of physically examining all of the existing pipe segments is prohibitively expensive, on the order of millions of dollars; and the priority, timing and investigative approach for such a program cannot be reasonably determined without initially screening the inventory for risk factors. AECOM created a logical framework within which physical evaluation of high risk PCCP segments could be prioritized, have the appropriate investigative technique rationalized, and then budgeted for to facilitate implementation. The logical framework is a risk-based approach to initially assess both the probability of failure versus the consequence of failure for each pipe segment. Risk in this context, is the product of probability of failure times failure consequence in a traditional risk matrix. This comparative information was used to identify and prioritize pipe segments for subsequent physical evaluation.

AECOM performed a desktop analysis of TBW's existing PCCP segments (76 miles of pipe). The desktop analysis included an assessment of both the probability of failure and the consequence of failure for each pipe segment. The probability of failure portion of the desktop analysis was formatted and performed in a manner consistent with the "Long-Form Assessment Matrix" methodology described in *Failure of Prestressed Concrete Cylinder Pipe* (Romer, et al. - AWWA Research Foundation, 2008). The desktop analysis incorporated data about existing PCCP pipe segments provided by TBW. The data was spatially referenced and was supplemented with soils information from the US Geological database to assist in characterizing external environmental exposure risk.



The desktop analysis of each PCCP segment was based on the 38 failure probability factors described in the above-referenced AWWA document. In general, these 38 factors can be grouped as follows:

- Design-related factors (3)
- Manufacturing-related factors (10)
- Inspection related factors (6)
- Construction related factors (8)
- Operation and Maintenance related factors (4)
- Pipeline Condition indicating factors (7)

Statistical analysis of the compiled data was performed to generate the probability of failure results for each pipe segment.

Through discussions with TBW, a simplified consequence of failure score was developed for each PCCP segment. The consequence of failure will consider the extent of loss of service criteria and cost of repair criteria.

EXAMPLE OF A HIGH-CONSEQUENCE PIPELINE:
A single, 54-inch pipeline conveys raw water from the South Central Hillsborough Well Field to the treatment plant. This pipeline is 25 years old and approximately 31,000 feet in length. If this pipeline suffers a catastrophic failure, the impact to operations is expected to be extreme. It may not be possible for TBW to meet some Average Day Member Government demands if this pipeline fails and is not in service.

The probability of failure results derived from analysis of PCCP data was utilized in conjunction with the consequence of failure score to quantify risk for each PCCP segment. Segments with the highest risk (e.g., those that score high in both probability of failure and consequence of failure) were recommended for subsequent investigation. Based on the nature of factors that drive the high risk factors, a specific direction for subsequent investigations was recommended. Subsequent investigations varied dependent on the risk drivers from physical investigations at varying levels of technological sophistication to operationally driven investigations in an attempt to better quantify risk.

AECOM's deliverable for this assignment as in the form of a Technical Memorandum. The Technical Memorandum presented the findings of the desktop analysis and included pertinent data, calculations, maps and a roadmap forward.

Guidelines for the Design, Procurement and Construction of Large Diameter Transmission Pipe

Calgary, AB, Canada

Client
City of Calgary

Total Project Cost
$170,000 (Canadian)

Contact
James A. Buker, P.Eng.
Project Engineering - Underground Infrastructure Delivery
Water Resources #436
P.O. Box 2100, Station M.
Calgary AB, Canada T2P 2M5
403.268.5716
jbuker@calgary.ca

As a result of the spectacular and catastrophic failure of a 1200 mm (48") feeder main on McKnight Boulevard, the city of Calgary engaged AECOM to conduct a complete and thorough review of the City's transmission design standards, and to develop new transmission pipeline material specifications.

Historically, the city had utilized AWWA C301 PCCP, AWWA C303 CPP and steel transmission mains, using a variety of historical specifications. AECOM researched the history of specifications used in Calgary, including the development history of AWWA standards, for AWWA C300 series concrete pressure pipes, AWWA C200 steel pipe and a variety of tape, mortar, and interior and exterior di-electric coating products.

Reviews were also conducted on various failure mechanisms for various pipe products, such as ettringite and thaumosite forms of sulphate attack, and chloride penetration on concrete pipes and mortar coatings.

Design manual reviews were also conducted on thrust restraint practices, cathodic protection, and installation practices. A standardization of various pressure class terminology was also developed to allow for a more direct comparison of the various nomenclature utilized in the pipe industry.

The resulting design manual and standard specifications have been in practice since 2012. Innovative specification features, such as use of silica fume mortars to dramatically reduce mortar absorption and increase resistance to sulphate attack and chloride penetration, have been adopted.

WATER SUPPLY AND FEEDER MAIN CONDITION AND RISK ASSESSMENT

REGINA, SK, CANADA

AECOM developed and implemented a risk-based condition assessment program for all 170 miles of critical water main inventory in Regina, SK, (population 200,000).

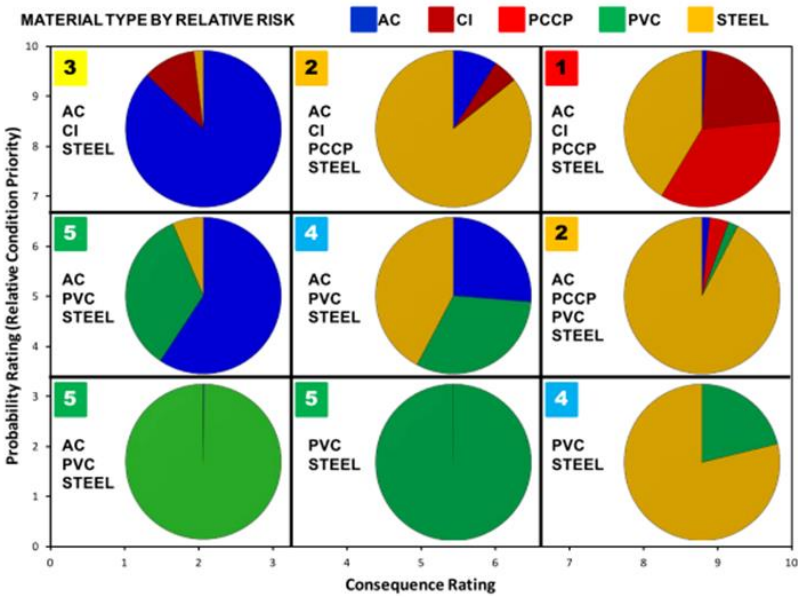
The existing critical water main inventory was compiled in a manner that facilitated risk-based condition assessment, assessing initial condition of the inventory based on deterioration risk factor assessment techniques, and providing a clear road map forward to balancing cost and failure consequence in an overall risk model.

Client
City of Regina

Total Project Cost
$350,000 (Canadian)

Contact
Yafei Hu
Project Engineer
City of Regina
YHU@regina.ca

The project involved an extensive review of existing failure records, prioritization processes (for condition assessment and rehabilitation), and the development of both consequence and failure models for an inventory that includes ferrous metal pipelines (steel and CI/DI), cementitious based pipelines (PCCP and AC) and thermoplastics (PVC and HDPE). Deterioration drivers were captured for each pipe material, and condition assessment technologies were mapped to specific performance deficiencies and materials based on their overall risk profile. The first phase of work was completed in 2012/2013. In the Phase 2 program, a series of field investigations of pressure pipe condition assessment were carried out using both advanced tools and traditional techniques to develop a "toolbox" of both screening tools and advanced continuous measurement tools to support a long term condition assessment program.



CONDITION ASSESSMENT AND REHABILITATION OF A CRITICAL WATER MAIN WITH CFRP TECHNOLOGY

HAMILTON, ON, CANADA

AECOM was requested to assist in the provision of services to assess the cause of a catastrophic failure of a 48-inch diameter prestressed concrete pressure main and to develop and implement a remediation plan using advanced condition assessment and rehabilitation technologies.

In July of 2009, ARC Dofasco's main water supply ruptured, thereby severing water supply to the largest steel manufacturing plant in Canada. Condition assessment technologies included the deployment of remote field transformer coupling (RFTC) technology and the assessment of the residual strength of a number of pipelines at the plant of similar vintage.

The selected repair strategy involved the use of carbon fiber reinforced polymers (CFRP), and AECOM's service included the development of the applied loads model and the design protocol, the development of quality assurance requirements for the repair technology, and field services to confirm that the intended design objectives for repair were achieved.

Client
ArcelorMittal Dofasco (ARC Dofasco)

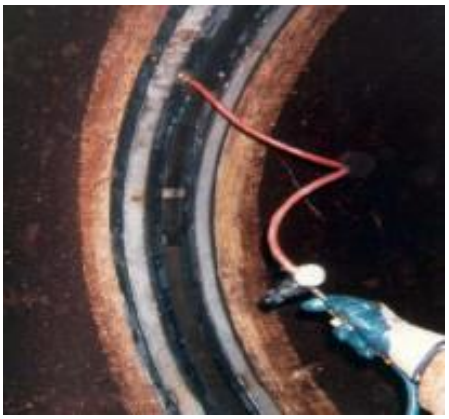
Total Project Cost
$1.2 Million ($229,500 Inspection, Assessment and Design and $1 Million Construction (Canadian)

Contact
Trevor Boppre, Project Manager,
ARC Dofasco
905.548.7200
trevor.boppre@arcelormittal.com

SHOAL LAKE AQUEDUCT CONDITION ASSESSMENT AND REHABILITATION

WINNIPEG, MB





AECOM collaborated with the city of Winnipeg Water and Waste Department and others in a 10-year program to assess the condition of the 160 kilometer (97 mile) long Shoal Lake Aqueduct and to design and oversee the undertaking of rehabilitation works necessary to extend the operational life of the pipeline a minimum of 50 years. Since completion of construction in 1919, the Shoal Lake Aqueduct has functioned as the sole means of conveying water from the intake located at Shoal Lake on the Manitoba-Ontario border to the city of Winnipeg. The Internal and External Repair Programs included analytical work, physical condition assessment, and the implementation of the necessary rehabilitation work to upgrade all internal and external features of the Aqueduct.

Client
Winnipeg Water and Waste Department

Total Project Cost
$58 Million (10-Year Program)

Contact
Ron Sorokowski
Senior Project Manager
112-1199 Pacific Avenue
Winnipeg, MB R3E 3S8
204.986.4472

The objective of this program was to restore the aqueduct's hydrostatic and structural integrity. Most of the cracks observed in the Aqueduct have been present since or shortly after original construction. In some cases, as in segments that exhibited severe offset cracking, the stability of the structure had been compromised. Restoring structural integrity was an essential priority in reducing the potential for a service failure of the water supply system. Infiltration of groundwater into the Aqueduct, or exfiltration of water from the Aqueduct, has and would continue to occur without remediation.

Continued leakage was considered unacceptable from many perspectives as it would compromise water quality, facilitate sulphate attack due to exfiltration of water into sulphate laden soils, and increase the potential for losing structural stability in the long-term.

The Aqueduct was constructed of unreinforced cast-in-place concrete for much of its length through rural Manitoba but with sections of reinforced precast and cast-in-place concrete in urban sections (referred to as the Branch I Aqueduct). The Aqueduct markedly improved the quality of life of the city of Winnipeg residents and continues to do so today, some 90 years after completion of the original project. Moreover, as a result of the Aqueduct Rehabilitation Program, it will provide a minimum of another 50 years of invaluable service.

The rehabilitation of the Shoal Lake Aqueduct began as a vision and a challenge. The vision was to extend the life of the structure to provide at least another 50 years of service with minimal to no increases in long-term maintenance and operating costs. The challenge was to plan for over 10 years of engineering and construction without spending any more than the utility-based fund established for the program. Largely completed in 2004, the project was completed at a cost of approximately $58 million.

The Aqueduct Rehabilitation Program included numerous inter-related projects in the following broad work areas:

- Condition Assessment, which included comprehensive structural, hydraulic and buoyancy assessments; internal and external physical condition assessment utilizing a variety of non-destructive and destructive testing technologies; and both short- and long-term monitoring programs to assess alternative repair technologies and advance the understanding of pipe-soil interaction.

- Repair Programs, including internal repair projects - polyurethane injection, invert stress repairs, pressure pipe joint repairs with compression seals; and external repair projects – both external strengthening with shotcrete and conventional cast-in-place concrete repair.

- Monitoring and Instrumentation Program involving the design and implementation of a SCADA system to monitor the operation of the Aqueduct on a continuous basis.

- Drainage improvement programs to assess, restore and upgrade right-of-way drainage features for the 135 km of the Aqueduct that transverses rural southeastern Manitoba.

- Information Management, which has included development of a WEB-based Information Management System to manage on-line all technical data pertaining to the operation of the Aqueduct.

The Aqueduct Rehabilitation Program has won the following Awards:

- 2001 CEM: Award of Excellence in Technology Innovation (Rehabilitation Program)

- 2002 APEGM: Certificate of Engineering Achievement (Rehabilitation Program)

- 2002 CEM: Award of Excellence in Technology Innovation (Seine Riverbank Stabilization Project Adjacent the Branch I Aqueduct)

- 2002 ACEC: Award of Merit (Seine Riverbank Stabilization Project Adjacent the Branch I Aqueduct)

3 Organizational and Project Team Qualifications and Experience

About AECOM

AECOM is a global provider of professional technical and management support services to a broad range of markets, including water, environmental, energy, facilities and transportation. AECOM is a leader in all of the key markets that it serves.

On October 17, 2014, AECOM completed its acquisition of URS Corporation. Now, with nearly 80,000 employees -- including architects, engineers, designers, planners, scientists, and management and construction services professionals -- serving clients in more than 150 countries around the world, AECOM offers clients greater scale and resources which enables us to provide fully integrated services across a broader range of end markets anywhere in the world. Our combined company is better positioned to deliver the integrated services that clients increasingly demand.

Legal Name of Firm:
AECOM

Local Address:
800 LaSalle Avenue
Minneapolis, MN
55402

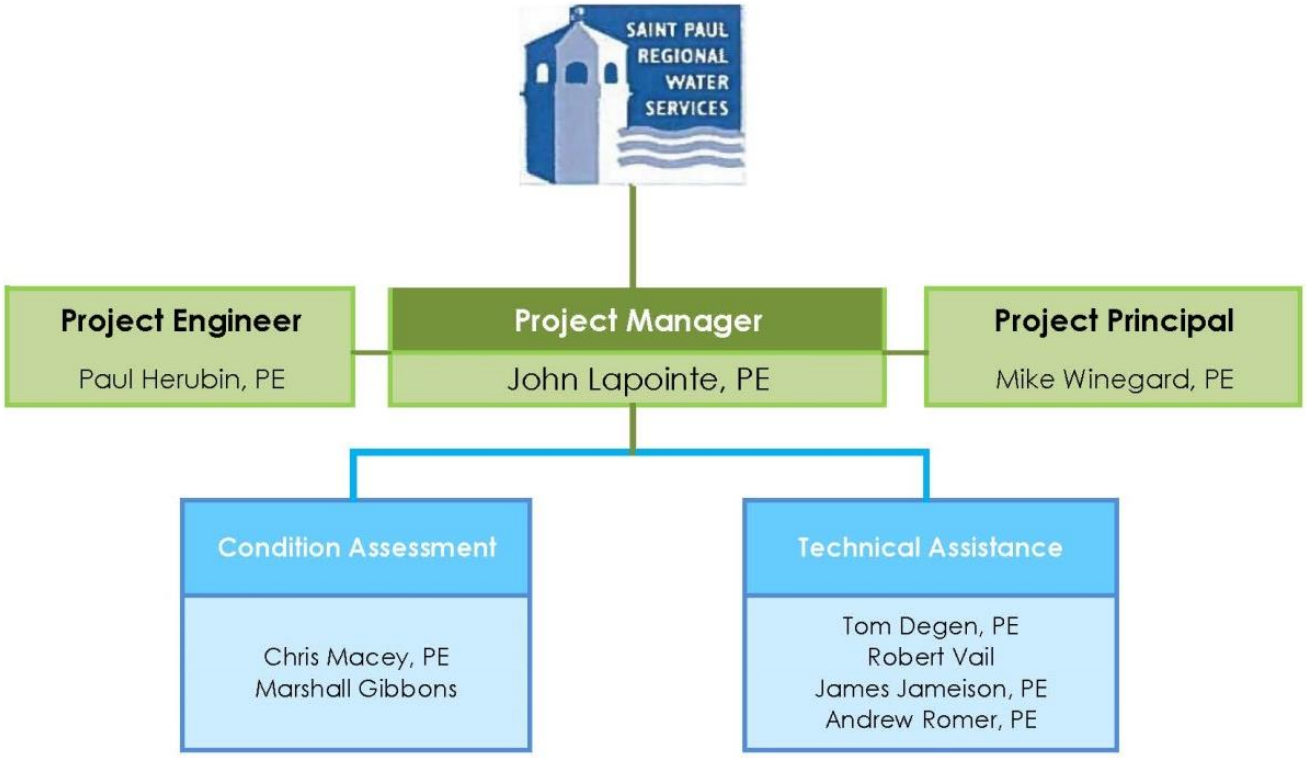
Local Contact:
John Lapointe, PE
Project Manager
612.376.2587
john.lapointe@aecom.com
www.aecom.com

180 **professional, technical and support personnel in Minnesota**

QUALIFICATIONS AND EXPERIENCE

This project requires a team comprised of expertise in larger scale condition assessment programs, materials assessment, and best practices for rehabilitation. AECOM's specialists employ a vast knowledge of virtually all pipe materials in gravity and pressure service. Our team is comprised of NACE certified experts in corrosion of both ferrous metals and cementitious materials. We have hands-on field assessment experience with traditional condition assessment techniques as well as a diverse array of advanced condition assessment technologies.

Our team includes John Lapointe, Project Manager; Paul Herubin, Project Engineer; Mike Winegard, Project Principal; Chris Macey, Condition Assessment Engineer; Marshall Gibbons, Materials Assessment Specialist; and Tom Degen, Technical Assistance. This team has worked together on many large-scale condition assessment projects for clients similar to SPRWS.



John Lapointe, Project Manager, will facilitate important and timely discussions with SPRWS throughout the project, as needed, and will provide a local point-of-contact for the SPRWS team. This approach will ensure an open line of communication will be established throughout the project and provide a direct transfer of information to SPRWS. Mr. Lapointe has managed many large projects for clients, including Waterloo, IA, and Minnesota Pollution Control Agency (MPCA).

Paul Herubin, Project Engineer, has extensive experience involving construction oversight of large diameter pipeline projects. ***Tom Degen*** will provide technical assistance throughout the SPRWS PCCP Condition Assessment project. Mr. Degen managed the Raw Water Conduit Assessment project for SPRWS, and has also managed numerous asset management and condition assessment projects for similar clients. Tom will work closely with the project team.

Team Member	General Background	Experience With Similar Projects
John Lapointe, PE **Project Mgr.**	☒ 40 Years of Exp. ☒ Range of Exp. Involving Water System Design, Condition Assmnt. & Construction in Twin Cities Metro Area	☒ Supervised Waterloo, IA, Interceptor Sewer Insp. for Army Corps of Eng. Levee Certification Program
Paul Herubin, PE **Project Engr.**	☒ 26 Years of Exp. ☒ Extensive Exp. on Construction Insp. of Large Dia. Pipe	☒ MCES, 72-In. Dia. FRP Interceptor, Victoria, MN ☒ Minneapolis, MN, Nicollet Mall Sanitary Sewer Replacement ☒ Carver, MN, 36" Dia. Interceptor Sewer
Mike Winegard, PE **Project Principle**	☒ 40 Years of Exp. ☒ Asset Mngmnt./Condition Assessment Projects Exp. ☒ Large Water Utilities Exp.	☒ Recent Large Water Utility Projects Inside Genesee Co., MI, & Bloomington, IL
Chris Macey, PE **Condition Assmnt. Engr.**	☒ 40 Years of Exp. ☒ AECOM National Technical Specialist for Condition Assmnt. & Rehabilitation ☒ SPRWS Raw Water Conduits from Previous Discussions & Expertise in Similar Climates Exp. & Knowledge	☒ SPRRWS Condition Assmnt. of Raw Water Conduits ☒ North Fork Siphon Condition Assmnt. ☒ Tampa Bay PCCP Failure Risk Analysis, Lead Eng. ☒ Calgary Guidelines for Large Dia. Pipe Design & Construction, Project Eng.
Marshall Gibbons **Materials Assmnt. Spec.**	☒ 28 Years of Exp. ☒ NACE Certified Corrosion Technician ☒ NACE Certified Cathodic Protection Tester ☒ NACE Certified Coatings Inspection, Level 1	☒ SPRWS Condition Assmnt. of Raw Water Conduits ☒ North Fork Siphon Condition Assmnt. ☒ Woodward-Greenhill Water Transmission Main Assmnt. ☒ Winnipeg Force Main Condition Assmnt.
Robert Vail, **Corrosion Engr.**	☒ 33 Years of Exp. ☒ NACE Intnl. Corrosion Specialist (G)#3705 ☒ NACE Intnl. Cathodic Protection Specialist #3705 ☒ NACE Intnl. Protective Coatings Specialist #3705 ☒ NACE Intnl. Certified Coating Inspector #7348	☒ Dallas Water Utilities, Southwest 120/96-In. Dia. Water Transmission Project Impressed Current & Galvanic Cathodic Protection for PCCP and Coated Steel Transmission Piping. ☒ Oklahoma City Water Utilities Trust Atoka Pipeline; Soil Corrosivity Testing and Cathodic Protection Design, 72" Dia. Steel Raw Water Line
James Jameison, PE **Corrosion Engr.**	☒ 43 Years of Exp. ☒ NACE Intnl. Corrosion Specialist (P) #3609 ☒ NACE Intnl. Cathodic Protection Specialist #3609 ☒ A Leading Corrosion Control Stray Currents Expert in USA	☒ MCES, Southwest Light Rail Transit Project. Minneapolis, MN.
Thomas Degen, PE **Tech. Asst.**	☒ 34 Years of Exp. ☒ AECOM Senior PM ☒ Expert in Water Main Risk-Based Prioritization Projects & Capital Planning ☒ Provided Asset Mngmnt./Condition Assmnt., Services for Numerous Utilities	☒ SPRWS Water Main Prioritization, PM ☒ DuPage Water Comm. Water Mains Condition Assmnt., Condition, Assmnt. Lead ☒ Appleton Water System Master Plan & Water Main Replacement Planning, Main PM ☒ Janesville, Water System Master Plan, PM
Andrew Rober, PE **Tech. Asst.**	☒ 39 Years of Exp. ☒ Member - AWWA Standards Committee on Concrete Pressure Pipe, PCCP, Rehabilitation of PCCP, and Manual M-9	☒ North Fork Siphon Condition Assmnt. ☒ North Dakota State Water Comm., Raw Water Main Transmission Pipeline Upgrades, Bismark, ND

JOHN LAPOINTE, PE
PROJECT MANAGER

Education
BS, Engineering Operations, Iowa State University - 1978

Licenses/Registrations
Professional Engineer - Minnesota, Iowa

Affiliations
American Water Works Association:
- AWWA 2005-2006 Chair of the MN Section
- AWWA 1998-2002 Association Membership Committee

Mr. Lapointe has been involved in the water system engineering field since 1978. His experience with the Iowa Department of Natural Resources (IDNR) and Minnesota Department of Health (MDH) included performing inspections of water treatment facilities and reviewing plans and specifications for compliance with state regulations and standards. He provided potable water treatment system design services to municipal, state and federal clients while employed at consulting firms in Iowa and Minnesota. Mr. Lapointe has expertise in the field of industrial water treatment, in particular the design of cold lime softening systems for industrial applications. He assisted on pilot studies which were used to develop the process for radionuclides removal using hydrous manganese oxides (HMO) treatment.

Some of Mr. Lapointe's water treatment, storage and pumping system experience is provided in the project summaries below.

PROJECT EXPERIENCE

St. Louis Park Utilities, WTP4 Improvements and Advanced Oxidation Process (AOP) WTP6, St. Louis Park, MN. Provided QA/QC review of projects designed to remove VOCs and 1,4dioxane from the municipal water supply wells.

Minneapolis Water Works, Columbia Heights Membrane Filtration Plant, Minneapolis, MN. Provided construction engineering services on $80 million ultrafiltration membranes treatment facility.

Minneapolis Water Works, Rehabilitation of Pump No. 14, Pump Station No. 4, Minneapolis, MN. Project engineer on the design and installation of a new 30 MGD centrifugal pump. Project included the installation of a new 1500 HP motor and a new 30-inch diameter ball valve.

Minneapolis Water Works, Lagoon Overflow Treatment Plant, Minneapolis, MN. Provided construction engineering services on $1.6 million addition to Water Works to accommodate recycling supernatant from on-site lime sludge lagoons.

Chicago South Water Treatment Plant Facilities Planning, Chicago, IL. Project engineer on study of 480 MGD Chicago-South Water Treatment Plant identifying capital improvement needs and costs.

Saint Paul Regional Water Services, Water Treatment Plant Aquatic Invertebrate Study, Saint Paul, MN. Project manager on an investigation to determine the sources of an infestation of aquatic invertebrates (caddis and midge flies) in the water treatment system. Prepared a report containing recommendations for controlling the aquatic invertebrate infestations.

City of Mankato, Water Treatment Plant Lime Sludge Handling Facility, Mankato, MN. Design engineer for site work and construction manager for entire project which involved a new lime sludge filter press dewatering system.

City of Hutchinson, Ground Storage Reservoir and Well No. 8, Hutchinson, MN. Project engineer for a 1.5 MG prestressed concrete water storage reservoir and 1,100 GPM water supply well.

City of Robbinsdale, Water Treatment Plant Upgrades, Robbinsdale, MN. Design and construction engineer for rehabilitation of 3 iron/ manganese removal horizontal pressure filtration plants.

PAUL HERUBIN, PE
SENIOR ENGINEER

Education
BS, Civil Engineering, Structural/Geotechnical, University of Wisconsin, Platteville - 1992

Licenses/Registrations
Professional Engineer - Illinois, Wisconsin, Minnesota

Affiliations
- Water Environment Federation
- American Water works Association

Mr. Herubin is a senior engineer with more than 26 years of experience with water and wastewater infrastructure, from planning and design through construction. His primary skills are in collection systems, water distribution systems, construction engineering and facility planning.

PROJECT EXPERIENCE

Metropolitan Council for Environmental Services, Blue Lake WWTP Levee Accreditation, Shakopee, MN. Project Manager for the preparation of a levee accreditation report for the original levee protecting the Blue Lake WWTP. This report specifically addressed levee freeboard, levee closures, embankment protection/stability, interior drainage, operations, and maintenance in accordance with 44 CFR 65.10 requirements. Performed hydraulic analysis, assisted Client with document gathering, coordinated sub-consultant with embankment stability analysis, and preparation of report for Client to submit to FEMA for accreditation.

Metropolitan Council for Environmental Services, Victoria, MN. Project Manager for the installation of approximately 7,100 lineal feet of 72-inch diameter FRP in soft ground conditions. Responsibilities included coordinating field construction inspector activities and project administration.

Metropolitan Council for Environmental Services, Brooklyn Park and Fridley, MN. Project Manager for the installation of a new 100 lineal foot, 42-inch dual barrel force main underneath the Mississippi River linking existing Lift Station L32 in Brooklyn Park with a gravity interceptor in Fridley. Responsibilities included coordinating field construction inspector activities and project administration.

Metropolitan Council for Environmental Services, Minneapolis, MN. Project Manager for the rehabilitation of MCES Interceptor MN-341 in Minneapolis. Project involved televising, cleaning, and installing CIPP liner of 10,500 lineal feet of interceptor sewer ranging in diameter from 27 inches to 60 inches. Temporary conveyance systems were incorporated during the work. Responsibilities included coordinating field construction inspector activities and project administration.

City of Carver, Interceptor, Carver, MN. Project Manager for the gravity portion of the interceptor. Overall project consisted of 7,000 lineal feet of 36-inch gravity sewer, two lift stations, 6,000 lineal feet of dual 24-inch force main, 15,000 square yards of roadway replacement, and State Aid improvements. This project also included the abandonment of 9 STEP stations, 2 city lift stations, and the eventual decommissioning of the existing wastewater treatment plant. Responsibilities included laying out alignment and construction limits, coordinating with other disciplines, meeting with stakeholders, and directing the preparation of preliminary plans and specifications.

Metropolitan Council for Environmental Services, Lift Station L-30, Crystal, MN. Project Engineer for a lift station rehabilitation. Project consisted of architectural, structural, electrical and mechanical upgrade of an 8 MGD lift station that was constructed in 1955. Incorporated record drawing information into plan set and identified temporary conveyance options.

PAUL HERUBIN, PE - CONTINUED

Metropolitan Council for Environmental Services, Lift Station L-7 Force Main, Mahtomedi, MN. Project Engineer for the design of a dual force main. Project consisted of 10,000 lineal feet of dual 16-inch force main, six air release valves, eight cleanout structures, and 10,000 square yards of bituminous roadway restoration. Performed routing alternatives analysis and hydraulic analysis, laid out alignment and construction limits, identified temporary easements, met with stakeholders, and prepared preliminary plans and specifications.

City of Minneapolis, Nicollet Mall Sanitary Sewer Replacement, Minneapolis, MN. Process Engineer on a project which identified and assessed the feasibility of applying proven trenchless sewer constructability methods and constructability issues for a sanitary sewer replacement along the Nicollet Mall corridor. This sewer replacement project consisted of 3,500 feet of sanitary sewer ranging from 12-inch to 24-inch, with numerous conflicting underground utilities. Responsibilities included: identifying proven trenchless sewer installation methods; assessing directional drilling and micro-tunneling methods; assessing constructability and staging; and cost estimate.

City of Minneapolis, Pump Station No. 5 Condition Assessment, Fridley, MN. Project Manager for the condition assessment of Pump Station No. 5. The project goal was to assess the remaining useful life of the Pump Station No. 5 facility and major pieces of equipment. This study assessed architectural, structural, process, electrical and HVAC components. Tasks included on-site inspections, identification and prioritization of upgrades, phasing and budgeting of upgrades, and report writing.

City of Edina, Edina Water Treatment Plant No. 6, Edina, MN. Resident Engineer responsible for on-site inspection to ensure contract compliance; conflict resolution between contractor and client; change order negotiation and preparation; concrete and soil testing coordination with AECOM testers and laboratory; design change and clarification coordination with multi-office AECOM design team; pay application review and verification; and plant start-up coordination.

City of Minneapolis, Fridley Ammonia Building, Fridley, MN. Resident Project Representative for the construction of a $4.6 million ammonia storage and injection facility. Responsibilities include: on-site inspection to ensure contract compliance for architectural, structural, mechanical and electrical disciplines; conflict resolution between contractor and client; change order negotiation; special inspection coordination with third party testing firm; pay application review and verification.

City of St Louis Park, SLP 4 WTP Improvements, St Louis Park, MN. Resident Engineer responsible for on-site inspection to ensure contract compliance; conflict resolution between contractor and client; change order negotiation and preparation; concrete and soil testing coordination with 3rd party testers and laboratory; design change and clarification coordination with multi-office AECOM design team; pay application review and verification; and plant start-up coordination.

MICHAEL WINEGARD, PE
PROJECT PRINCIPAL

Education
MBA, Finance, Loyola University - 1980
BS, Civil Engineering, Marquette University - 1977

Licenses/Registrations
Professional Engineer - Wisconsin, Indiana, Michigan, Pennsylvania

Affiliations
- American Water Works Association Mid-Central Water Works Association
- National Association of Water Companies Ground Hog Club of Chicago American Metropolitan Water Association

Mr. Winegard has more than 40 years of experience in municipal water systems and has been responsible for the design and analysis of entire potable water systems. His extensive experience in working for communities throughout the Midwest makes him ideally suited to oversee the quality control for this project.

PROJECT EXPERIENCE

Genesee County, New Water Treatment Plant, Genesee County, MI. Project manager for a new 30 MGD conventional water treatment plant which, while approximately 30 miles inland, will treat water from Lake Huron. The 30 MGD plant is planned to have two 15 MGD treatment trains so that if one is down for maintenance and/or repairs, the plant can still be in service, albeit at a reduced overall capacity. The water treatment plant and auxiliary facilities at the treatment plant will include: unit processes: receiving reservoir, rapid mixing, flocculation, clarification/ sedimentation, gravity filtration, chemical storage and feed, disinfection and fluoridation, finished water storage, finished water pumping, laboratory and maintenance area, and waste reclamation and disposal. Chemical storage and feed facilities include potassium permanganate to aid in oxidations of minerals and organics, powdered activated carbon for taste and odor control, coagulants for flocculation, polymer to enhance/aid the filtration process and improve sludge settling, phosphate to act as a corrosion inhibitor, and chlorine for disinfection and fluoride.

City of Bloomington, Water Treatment Plant Master Plan, Bloomington, IL. Responsible for a master planning study of water treatment, based on achieving an overall capacity goal of 30 MGD, which involved evaluating each component of the water treatment plant, from the source water to the finished water transmission mains, for deficiencies in meeting this goal and possible solutions or alternatives to improve these deficiencies. Also assisted in providing opinions of probable cost, recommendations, and priority of improvements.

Muscatine Water and Power, Water System Infrastructure Assessment, Muscatine, IA. Involved in preparation of water master plan in 2011 for Muscatine Power and Water. The master plan involved creating a hydraulic model utilizing the InfoWater software package. Current water demands were analyzed and future water demands were projected for both average and maximum days for the years 2011 and 2030. Comprehensive distribution system analyses, including fire flow and water age analyses, were conducted. In addition to the water distribution system, AECOM investigated the water supply (groundwater), water treatment, storage and pumping. A capital improvements plan was prepared, along with a prioritized list of when the improvements should be implemented.

Water System Additions, Lake Township, MI. Staff engineer for the design of several additions to this water distribution system, including an emergency interconnection to the city of Bridgman; design engineer for engine-generator facilities at the water treatment plant and raw water pumping station; and project engineer for an administrative addition to the water treatment plant, as well as an additional 500,000-gallon

MICHAEL WINEGARD, PE - CONTINUED

reinforced concrete reservoir built partially below ground.

City of South Haven, Water Filtration Facility Rehabilitation, South Haven, MI. Project director for filter rehabilitation at the South Haven, MI, water treatment plant, which included replacing filter underdrains and media and adding filter to waste piping, turbidity meters and particle counters.

City of Battle Creek, Radon, Iron and Manganese Removal Facility, Battle Creek, MI. Managed design for a new 30 MGD iron, radon and manganese removal plant for the Water Department. The designed plant included microcomputer-operated supervisory control and data acquisition system instrumentation and filtration facilities for treatment of the city's groundwater supply, as well as the upgrading of the existing chlorination system, all necessary chemical feed facilities, instrumentation and controls, and all required architectural, mechanical, and electrical appurtenances.

City of Galesburg, Water Treatment Plant Relocation, Galesburg, IL. Project director responsible for the design of new water treatment facilities near supply wells 30 miles west of the city to replace the plant downtown, which included raw water pumping, aeration, contact tanks, filtration, storage, high service pumping, sludge lagoons, phosphate, chlorine and fluoride feedings.

Indiana-American Water Company, Inc., Water Filtration Plant Assessment, Ogden Dunes, IN. Participating in an evaluation of potential waste-handling alternatives and improvements at a water filtration plant for the Indiana-American Water Company, which includes an assessment of current operations, calculation of theoretical sedimentation basin sludge and filter backwash water volumes, and development of probable construction and life-cycle costs.

Village of Glencoe, Ultraviolet/Membrane Feasibility Study, Glencoe, IL. Project director responsible for a feasibility study to add ultraviolet or membrane technology to the water treatment plant for additional disinfection, which included the evaluation of life-cycle and operations and maintenance costs between these two alternatives.

Genesee County, North Water Loop Phase III, Henderson Road Pump Station, Flint, MI. Project director for design of a 30 MGD pump station and two 10-million gallon storage reservoirs for Phase III of the North Water Loop for Genesee County Drain Commission Water and Waste Services, which included a conventional 30 MGD pump station with an initial three pumps, and provision for expanding to a future 70 MGD pump station housing six pumps. Also responsible for a conceptual design for a future membrane water treatment plant at a nearby site, including two 10-million gallon precast, prestressed concrete reservoirs and all the necessary yard piping and appurtenances, as well as design of 18.5 miles of 36-inch diameter water main and 4.4 miles of 48-inch-diameter water main.

City of East Moline, Water Treatment Plant Engineering Study, East Moline, IL. Managed an engineering study for the 10 MGD conventional water treatment plant that included an evaluation of the treatment facilities and a recommendation for improvements to comply with current and anticipated regulations.

CHRIS MACEY, PE

CONDITION ASSESSMENT ENGINEER

Education
BSc, Civil Engineering, University of Manitoba - 1977

Professional History
3/1978 - AECOM - Project Engineer, Senior Project Engineer and Senior Program Manager; National Technical Specialist and Senior Technical Director Since 2000; Americas Technical Practice lead Since 2012

Affiliations
- Association of Professional Engineers and Geoscientists of the Province of Manitoba
- Association of Professional Engineers and Geoscientists of Alberta
- Association of Professional Engineers and Geoscientists of Saskatchewan
- Association of Professional Engineers and Geoscientists of British Columbia
- Professional Engineers Ontario

Training and Certifications
Cathodic Protection Design, University of Wisconsin at Madison, 1985

Chris Macey, P. Eng. is the Americas Technical Practice Lead for work pertaining to the assessment and rehabilitation of sewer and water infrastructure for AECOM. Since 1978, Chris has worked as a Project Engineer, Project and Program Manager, Senior Technical Advisor and as a Senior Technical Specialist on a diverse array of projects and major programs for Cities across North America as well as global geographies. Chris is also one of AECOM's global Technical Practice Network leads for the Condition Assessment and Rehabilitation of Linear Infrastructure, a Technical Network dedicated to dissemination of best practices for existing technologies as well as the development of new technology and for AECOM and their clients globally.

Chris has considerable expertise in the assessment, design, and construction/rehabilitation of both sewer and water infrastructure. He has extensive knowledge of pipeline materials, pipe/soil structure design principles, pipeline deterioration processes and pipeline rehabilitation technology. He specializes in work where pipelines will be subjected to adverse conditions and in complex projects where minimum risk exposure is desired.

Chris is also very active in research on condition assessment and rehabilitation of pipes working on the following programs:

- Contributing author of AWWA Manual M77 – Condition Assessment of Watermains (on-going)
- WRF Studies
  - Water Research Foundation (WaterRF) RFP: 4498: Potable Water Defect Condition Rating
  - WaterRF PFA # 04553 - Guidance & Strategies to Determine when to use Condition Assessment Technologies on Highly Critical Water Mains
- AWWA Committee M28: Rehabilitation of Water Mains, including the following sub-committees:
  - Condition Assessment of Water Mains
  - Structural Classification of Water Main Liners (contributing author of white paper on Protocol for Structural Classification of Lining Systems for Water Mains
  - CIPP Lining of Water Mains
- Contributing Author to AWWA C620 Draft Standard Practice for the Application of Spray-Applied Polymeric Liners Inside Pipelines for Potable Water
- Contributing author to the NASTT Best Practice Guidelines for CIPP (released 2015)

CHRIS MACEY, PE - CONTINUED

EXPERIENCE

Raw Water Conduit Assessment, St. Paul Regional Water Supply (SPRWS); St. Paul, MN. Senior Technical Specialist to facilitate the assessment of the condition of all 27 miles of raw water supply piping to the McCarrons Treatment Plant. The lines include Mississippi Conduits (#1 and #2; Conduit #1 constructed in 1924 of 1.6 miles riveted plate steel and 6.3 miles of cast-in-place reinforced concrete (CIPC);Conduit #2 constructed in 1958 is all steel); Pleasant Lake Conduits (Conduit #1 constructed in 1936 of 0.5 miles CIPC. Conduit #2 constructed in 1957 is all steel); and the Vadnais Lake Conduits (Conduit #1 constructed in 1925 of 4.4 miles CIPC; onduit #2 constructed in 1960 is all steel). Inspection technologies include CCTV (visual data capture with standard PACP protocol);Man-entry techniques (for visual inspection of key defects and ultra-sonic testing (UST)); external tests pipe, ECDA techniques and sampling and mechanical testing. The work commenced in 2016 and was completed in the summer of 2017.

Condition Assessment of "Metro Spec" Transmission Pipe to Facilitate the Finch West LRT (FWLRT) Program – Metrolinx – Toronto, ON, Canada. Senior Technical Specialist to carry out a condition and risk assessment of over 10 km of concrete encased, mortar lined steel pipe to facilitate the FWLRT. The pipe included 900 mm, 1200 and 1500 mm pipe with 21 unique design sections. A structural model was developed to assess the strength and vulnerabilities of the existing pipes versus its internal and external exposure conditions and loading changes contemplate by the LRT construction. Risk assessment was carried and mitigative measures were proposed to reduce deterioration rates in vulnerable sections to acceptable levels. The work was completed in 2015 and 2016.

Condition Assessment of the North Fork Siphon- Central Utah Water Authority - Duchesne County, UT. Development of a man entry inspection program and condition assessment of 1440 m (4712 feet) of 1800 mm (72") diameter prestressed concrete cylinder pipe (PCCP) siphon. The siphon had been inspected twice with very conflicting results with RFTC technology and needed to be visually inspected by man entry techniques to clarify its true condition state. Entrance slopes of 55 and 70 degrees, respectively, and a 221 m (727 foot) drop made access logistics and inspection planning very complex. The primary objectives of the assessment were to assess residual useful life, rehabilitation requirements and recommended timing for same. The project was successfully completed in the last quarter of 2016 and 1st quarter of 2017.

Assessment and Rehabilitation of Potable Watermains – Colorado Springs Utilities – Colorado Springs, CO. Senior Technical Specialist to facilitate the review of existing condition assessment, prioritization and rehabilitation programs for a utility with 1960 miles of watermain infrastructure (including cast iron, ductile iron, PVC, HDPE, steel, PCCP and AC pipe). The work is on-going and has involved the development of a new consequence model, condition assessment rating framework, and the rationalization of future condition assessment technology use for the Utility. Work in 2014 through 2017 focussed on the implementation of recognized condition assessment techniques for watermain infrastructure as well as the introduction of advanced rehabilitation techniques to improve the overall program cost effectiveness and reduce the impact of renewal on the consumer. Work in 2018 has focused on the development of a predictive model to relate overall investment levels in the system to service levels for various rehabilitation treatment approaches.

Watermain River Crossing Assessment for the City of Winnipeg, MB. As part of the Watermain Criticality Study development of a Risk Model and Condition Assessment Program to assess all 71 watermain river crossings within the City of Winnipeg. Implementation of pilot programs to assess the technical validity of condition assessment methodologies and development of a long-term river crossing assessment and rehabilitation program. Development of design, construction, and risk management guidelines to be employed for all existing and future watermain river crossings in the City of Winnipeg.

Chicago Department of Water Management, Chicago, IL. Design and quality assessment of a 16" CIPP AWWA M28 Class IV Liner in a ductile iron host pipe crossing a US Interstate. Assessment include development of visual acceptance, forensic review of wetout, curing and installation logs, and all testing results of mechanical properties. Project completed in 2015.

CHRIS MACEY, PE - CONTINUED

Chicago Department of Water Management, Chicago, IL. Design and quality assurance reviews for rehabilitation of 48" (1200 mm) and 54" (1350 mm) PCCP watermains in seven (7) different pipe runs using carbon fiber reinforced polymer (CFRP) techniques. The rehabilitation was intended to interchange improvements on FAI Route 90/94 at II-290 Congress Parkway (Jane Byrne Interchang) Harrison to Polk Street in Chicago, IL. The project commenced in 2017 and is scheduled for completion in 2018.

Watermain Rehabilitation with AWWA Class IV Liners, Winnipeg, MB Canada. Preliminary design, detailed design and contract administration to facilitate the rehabilitation of 8", 10" and 12" cast iron host pipes with fully structural AWWA Class IV liners. Project includes development of master specification for CIPP, development of quality assurance requirements to detail Class IV liner structural requirements and confirm that these have been achieved in the construction phase, tendering and the provision of engineering services during construction. Project was completed in 2017.

Failure Investigation, Condition Assessment, and Rehabilitation of all PCCP pipe at the ArcelorMittal Dofasco Steel Plant in Hamilton, ON. Failure investigation was of a 1219 mm (48") lined cylinder type PCCP that failed catastrophically in August 2009. Condition assessment included the use of both screening technologies and the deployment of remote field transformer coupling (RFTC) inspection techniques while the rehabilitation program in late 2010 utilized carbon fibre reinforced polymer technology (CFRP). The quality assurance program developed for the rehabilitation program successfully implemented $1 million worth of repairs in a 132 hour shutdown.

Risk-Based Condition Assessment Model Development and Initial Inventory Screening – Tampa Bay Water Tampa Bay, FL. Senior Technical Specialist to carry out a desk-top risk analysis of 63 miles of Prestressed Concrete Cylinder Pipe (PCCP) piping in service in TBW's water transmission system ranging from 20 inch through 84 inch diameter. The objective of the program was to provide TBW with a prioritized list of PCCP segments to physically investigate, if desired, and to provide TBW greater insight into the probability of failure of these pipelines. The project involved the development of a full blown consequences and failure probability risk model, with the failure probability driven by an AwwaRF "Long-Form Assessment Matrix" methodology to quantify failure risk factors for PCCP pipe.

Water Supply and Feeder Main Condition and Risk Assessment - Regina, SK, Canada Senior Technical Specialist to develop and implement a risk based condition assessment program for 175 miles (275 km) of critical watermain inventory in Regina, SK, (population 200,000); compiling the existing critical water main inventory in a manner that facilitated risk based condition assessment, assessing initial condition of the inventory, and providing a clear road map forward to balancing cost and failure consequence in an overall risk model. The project involved an extensive review of existing prioritization processes (for condition assessment and rehabilitation), and the development of both consequence and failure models for an inventory that includes ferrous metal pipelines, cementitous based pipelines and thermoplastics. Deterioration drivers were captured for each pipe material, and condition assessment technologies were mapped to specific performance deficiencies and materials based on their overall risk profile.

Watermain Lining and Specification Development for Class IV Liners – Regina, SK, Canada. Senior Technical specialist involved in the assessment of a 400 mm diameter AWWA M28 Class IV Liner failure and its remediation in 2012 and 2013. Work included assessment of the existing liner (visual assessment, testing and assessment of its adequacy to meet design objectives), rationalization of a remediation approach to meet design objectives and development of a quality assurance program to remediate the liner. Work also included development of a Specification Template for future Class IV lining projects complete with recommended product, design, installation, technical submission, and quality assurance requirements to install AWWA M28 Class IV liners.

CHRIS MACEY, PE - CONTINUED

Watermain Criticality Study for the City of Winnipeg, MB. Specialist Adviser for the development of a criticality model to assess the relative importance of each watermain within the City of Winnipeg and including the rationalization and development of condition assessment technologies and rehabilitation technologies to be deployed on water infrastructure throughout the City of Winnipeg.

City of Winnipeg – Deacon Reservoir Facility Remediation of Reservoir Interconnection Pipelines. Senior Technical Advisor for development of conceptual and detailed designs, and contract administration for repairs to reservoir interconnection piping using slip lining techniques, at the Deacon Reservoir site. Key project challenges included development of water supply, risk mitigation and contingency planning to ensure the water supply is maintained in a low risk state during the Works. Final design utilized specialized construction techniques including diver installed pressure bulkheads for workspace isolation, diver supported installation of the largest size HDPE pipe available in North America and specialized low density cellular concrete annular grout. Project successfully completed in 2013. Project also won ACEC Manitoba Award of Merit in 2014.

Water Transmission Piping Standard Practice Guidelines – Calgary, AB. Review of all existing practices and the development of a Standard Practice to facilitate the design, procurement, and installation of all transmission pipe for the City of Calgary (all pipes in excess of 500 mm in diameter). The Standard Practice involves PCCP, steel, and PVC pipelines and appurtenances. Steel and PCCP pipe standards included comprehensive reviews of coatings, linings, and corrosion protection requirements for long term use in adverse soil conditions.

Watermain Condition Assessment – Cary, NC. Senior specialist advisor to facilitate the development of staged watermain condition program for 163 miles of AC pipe inventory in Cary, NC. Established condition assessment protocols to secure field samples and information, .introduced best practice criteria for the effective selection and application of suitable assessment techniques, and developed a decision tree to match the application of assessment techniques given pipe characteristics and environmental constraints.

City of Hamilton, Woodward-Greenhill Water Transmission Assessment, Hamilton, Ontario. Senior Technical advisor for program development and implementation of a phased field inspection program to assess the condition of the city's 6.2 km (3.8 mi) PCCP Woodward-Greenhill water transmission main. Phase 1 investigations included historic data reviews, site inspections and preliminary corrosion surveys. Phase 2 investigations included soil and groundwater sampling, additional corrosion surveys, leak surveys, pipe inspections and loading analysis, while Phase 3 included the deployment of RFEC technology utilizing the PPIC "PipeDiver" inspection unit.

Feedermain Valve Chamber Inspection Program – City of Winnipeg, MB. Senior Technical Specialist for the inspection and assessment of 229 feedermain valve chambers and all related elements including the valves, valve chamber structure and all functional appurtenances. A risk-based assessment program was developed and successful delivered to assess all feedermain valve chambers in inventory for a City of 700,000 people.

City of Winnipeg – Water Treatment Plant Protected Connections Program. Senior Technical Advisor for the detailed design and Contract Administration for development and construction of separation between raw and treated water sources at the Water Treatment plant site. Project includes modifications and retrofitting large diameter pipelines (> 1500 mm diameter), valves, chambers to develop and monitor safe "air gap" features between raw and treated water supplies. Key elements of the project include water supply and contingency planning to construct the works without major disruption to treatment and water supply system operations. Project was completed in 2014.

CHRIS MACEY, PE - CONTINUED

City of Winnipeg – Replacement of Branch I Aqueduct Valve and Meter Chamber. Senior Technical Advisor for construction of a 1200 mm valve and meter chamber on the Branch I Aqueduct. Project included site selection and design of an off-line chamber, and reconnection of new1200 mm PCCP pipe to existing vintage reinforced concrete pressure pipe. Accurate construction planning and staging were required to facilitate complex off line reconnection geometry in minimal timeframes.

PCCP Management Plan – Luck Lake & Riverhurst Pipelines - Saskatchewan Agriculture, Food & Rural Revitalization. Specialist advisor for the Condition Assessment and development of a 10 upgrading and risk mitigation plan for 74 km (46 mi) of large diameter PCCP in pressure service. The line was exhibiting premature failures from a balance of installation deficiencies in conjunction with exposure to adverse soil conditions. The 10 year plan upgraded service levels at the least cost to meet the owner's stated risk tolerance for failure.

City of Hamilton, LRT Impact Study, Hamilton, Ontario. Provided Senior Advisor input into assessing the potential impacts to existing sewer and water infrastructure due to the construction of a DC-powered Light Rail Transit (LRT) system. Provided input into structural assessment techniques, loading assessment and characterizing primary material degradation drivers.

City of Abbotsford, Quality Assurance Inspections and Assessment for the Gladwin Road Transmission Main and Norrish Creek Intake Replacement Projects, Abbotsford, BC. Senior Technical Specialist for quality assurance assessment of two steel water main projects ranging from 1050 mm through 1200 mm in diameter being constructed in mountainous terrain. The Gladwin Transmission Main project involved 5.85 km of 1200 mm pipe operating at pressures up to 2.75 MPa (400 psi) while the Norrish Creek intake was a low pressure application with 1.5 km of 1050 mm pipe. Assessment included a review of the quality of plant- and field-applied coatings being provided, a review of all third-party inspection and contract administration services being provided to the owner, and recommended updates to the procurement and inspection practices moving forward for steel pipe in critical service.

Emergency Repair of 2134 mm PCCP Pipe, Winnipeg. MB. Lead professional to determine cause and implement an emergency repair on a 2134 mm diameter PCCP pipe that was 12 m below grade. The pipe was one of two lines supply the Deacon Booster Pumping Station and its removal from service necessitating determining a revised operating mode to supply water to a City of over 700,000 people. A revised operating was developed in less than 24 hours, however, the City was put in a depleting storage supply mode. The cause of the leak was able to be determined in 72 hours without excavation. An emergency repair method was developed and the main was safely restored to service within 7 days from the initiation of the failure.

Assessment and Rehabilitation of the Shoal Lake and Branch I Aqueduct. Program Manager for the Aqueduct Rehabilitation Program. The Aqueduct Rehabilitation Program was a $57 million multi-year program rehabilitating the 97 mile (160 km) concrete pipeline that serves as Winnipeg's sole source of water (originally constructed from 1913 to 1919). The project involved comprehensive condition and hydraulic assessments for a complex gravity flow parabolic arch cross section as well as numerous circular siphons and both precast and cast-in-place concrete pressure pipe. The program also developed and implemented of a number of rehabilitation strategies to extend the useful life of the structure another 50 years. The overall program included:

- Condition Assessment including comprehensive structural, hydraulic, and buoyancy assessments; internal and external physical condition assessment utilizing FEA models, a variety of non-destructive and destructive testing technologies; and both short and long-term monitoring programs to assess alternative repair technologies and advance the understanding of pipe-soil interaction for a complex concrete structure.

CHRIS MACEY, PE - CONTINUED

- Repair Programs including internal repair projects - polyurethane injection, invert stress repairs, pressure pipe joint repairs with compression seals; and external repair projects – both external strengthening with shotcrete and conventional cast-in-place concrete repair.

- Hydraulic Assessment Program – development of a highly discretized hydraulic model and assessment of all Aqueduct capacity issues ranging from the impact of biofilm, increased surface roughness, and repair impact; development of detailed dewatering and recharge protocols to facilitate flow interruption planning and implementation, and emergency response planning.

- Emergency Response Assessment and Planning – review and assessment of a number of site specific emergency response risks as well as overall development of emergency response frameworks for key failure/exposure risks. The work area ultimately lead to the implementation of a comprehensive Monitoring and Instrumentation Program that included the design and implementation of a SCADA system to monitor the operation of the Aqueduct on a continuous basis.

- Drainage Improvement Programs to assess, restore, and upgrade right-of-way drainage features for the 135 km of the Aqueduct that transverses rural south-eastern Manitoba.

- Information Management, which included development of a WEB-based Information Management System to manage on-line all technical data pertaining to the operation of the Aqueduct.

City of Winnipeg – Shoal Lake Aqueduct Intake Condition Assessment. Senior Technical Advisor for a comprehensive condition assessment of the SLA intake facility. Project including a complete review of the entire facility and surrounding compound, covering review of all disciplines of the facility. Result of the project was a comprehensive condition assessment report and recommendation for enhancements and upgrades.

Sewer Rehabilitation Program Management and Implementation -Toronto Water – Toronto, ON. Senior Technical Advisor and Specialist to deliver Toronto Water Sewer Rehabilitation Program from 2018 through 2023. The program has a capital value of approximately $300 million and is focused on maximizing the use of trenchless rehabilitation technologies with minimal construction footprint.

Sunrise Highway Aqueduct Investigation and Assessment – Nassau County, NY. Senior Technical Specialist to assess the condition of approximately 9.1 miles of a seventy-two (72") inch diameter steel water main originally constructed in 1908 and not in use since 1966. The objective of the assessment was to determine the feasibility of re-purposing the pipeline into a force main to convey treated wastewater effluent from the Bay Park Sewage Treatment Plant to the Cedar Creek Water Pollution Control Plant. The work was carried out in the first half of 2017 using a balance of multi-sensor instrumentation (MSI) inspection technology, planned sampling and metallurgical assessments, and comprehensive structural modeling. The line was deemed to be suitable for re-purposing to meet the Owner's technical objectives by structural lining with either CIPP or discrete pipe relining technologies.

Regionalization Implementation Program, ALCOSAN, Pittsburgh, PA. Senior Technical Specialist and Program Advisor for the assessment and rationalization of rehabilitation requirements for an inventory expanding from 90 miles of gravity sewer infrastructure and associated appurtenances up to 4000 miles of pipe. The inventory includes pipes up to 96" in diameter. The work involves development of a consequence model, detailed condition assessment and an overall risk model as well as the conversion of an automated of rehabilitation stream generation to final rehabilitation rationalization and implementation. The work commenced in 2017 and is scheduled for completion in 2022. It is envisaged that the rehabilitation program will include approximately $500 million worth of upgrading with a diverse array of trenchless technologies, the majority portion of which, however, will utilize CIPP rehabilitation techniques.

CHRIS MACEY, PE - CONTINUED

Phase I Assessment and Rehabilitation of Sewer Mains in Colorado Springs, CO – Colorado Springs Utilities (CSU) – Colorado Springs, CO. Senior Technical Specialist to develop a framework for assessment, rehabilitation and optimization of operation and maintenance activities for all wastewater collection sewers in CSU's inventory. The primary driver for a large portion of the work was to rationalize the appropriate magnitude and prioritization of condition assessment assignments and the conversion of the condition assessment data in a consistent manner to appropriate rehabilitation and operation and maintenance work streams. Further, the work includes the development of an overall sustainable funding model to relate the level of investment into the Sewer Program to resulting levels of service. Work commenced in 2018 and is scheduled to be completed in early 2019.

Regionalization Pilot Program, ALCOSAN, Pittsburgh, PA. Senior Technical Specialist and Program Advisor for the initial assessment and rationalization of rehabilitation requirements of over 175 miles of gravity sewer infrastructure and associated appurtenances including pipes up to 96" in diameter. The work involved development of a consequence model, detailed condition assessment and an overall risk model as well as the automation of rehabilitation stream generation and final rehabilitation rationalization. The work was completed in 2015 and 2016.

City of Winnipeg Outfall Inspection Program – Winnipeg, MB. Senior Technical Specialist to assess and develop a risk-based remedial upgrading program for all 362 outfalls in inventory for a City of over 700,000. The outfalls ranged in diameter from 200 mm to 3700 mm in height and included 22,319m of outfall pipe. The inventory consisted predominantly Land Drainage pipe (69%) but included CSO's (14%), Relief Sewers (10%), and emergency WWs overflow (7%) and outfalls from all 3 WWTP's. The overall condition of the inventory was not well understood and the City desired to conduct a thorough condition assessment program to fully understand the level of investment necessary to sustain the asset and the best technological approach to extend the life of these critical assets. The program was completed in 2018.

Forcemain Risk Management Framework – City of Ottawa, ON. Senior Technical Specialist for the development and implementation developing and implementing a risk based condition assessment program for all 88 force mains in inventory in Ottawa, ON, (MSA pop. 1.2 million). Ottawa's force main inventory includes thermoplastic (PVC and HDPE), ferrous metals (ductile, cast iron and steel), cementitious (AC), and composite (PCCP) materials. In addition to physical condition, failure models and management strategies are being developed to manage hydraulic and odor control failures. The 88 force mains include pipe sizes varying from 150 mm (6") through 1050 mm (42") and over 96 km (60 miles) of pipe. The condition assessment toolbox includes a diverse array of analytical assessment tools for applied load analysis, leak detection, electromagnetic inspection and direct assessment techniques specifically tailored to optimize condition assessment for each force main. The project commenced in 2015 and is scheduled for completion in early 2018.

Critical Forcemain Condition Assessment – Raleigh, NC. Senior Technical Specialist to develop and implement of condition assessment program for 6 critical forcemain systems involving over 43 km (27 mi) of forcemain in diameters ranging from 200 mm (8") through 750 mm (30"). Materials include ductile iron (DI), PVC, HDPE, and CIPP lined DI. The project is on-going in 2018.

Sewer System Improvement Program (SSIP); Task Order 81 – Sewer Condition Assessment for SFPUC, San Francisco, CA. Senior Technical Specialist and Advisor for the implementation condition assessment projects to assess the physical condition and rationalize rehabilitation requirements for combined sewers over 36" in diameter, brick sewers, and special CSO structures in the City of San Francisco's inventory. The Task Order involves the deployment of specialized condition assessment technologies, rationalization of rehabilitation requirements and training of SFPUC staff in delivery of same. The Task Order commenced in 2017 and is on-going in 2018

CHRIS MACEY, PE - CONTINUED

Sewer System Improvement Program (SSIP); Task Order 21 – Sewer Condition Assessment for SFPUC, San Francisco, CA. Senior Technical Specialist and Advisor for the development of a framework and technology pilot implement to assess the physical condition and rationalize rehabilitation requirements for all combined sewers over 36" in diameter, all brick sewers, all 34 forcemains, and all special CSO structures in the City of San Francisco's inventory. Task Order commenced in 2013 and was completed in 2014.

Condition Assessment of all Forcemain Infrastructure in Virginia Beach, VA. Senior Technical Specialist for a three stage program to assess the physical condition of 196 miles of forcemain with 454 pumping stations including cast iron, ductile iron, AC pipe and to a lesser extent PVC and HDPE pipe. The program included the development of preliminary screening tool to assess condition based exposure risk factors, a comprehensive condition program using a balance of test pits, sampling, pipe-to-soil potential survey, linear polarization measurements and more advance tools such as RFEC technology. An applied loads model was developed for the entire inventory and deterioration projected to each discrete pipe segment to project failure risk in terms of a reduced factor of safety. The condition assessment data was overlaid with a consequence model to facilitate implementation of risk based management techniques.

High Risk River Crossings Condition Assessment for the City of Winnipeg, MB. Inspection of 19 pipelines at 14 separate crossing locations with advanced EM condition assessment technologies. The vast majority of this portion of the river crossing inventory are steel mains and the conveyance type includes wastewater siphons, wastewater forcemains, and watermains in diameters ranging from 250 mm through 800 mm (10" -32"). The primary inspection technology being used is remote field eddy current (RFEC) technology and the inspection program includes risk assessments to assess the viability of each deployment, a benefit-cost assessment, the development of an applied loads model, assessment of physical condition, rationalization of failure probability and, if required, a preliminary assessment of rehabilitation requirements. The program commenced in 2012 and had wastewater siphons and forcemains completed in the fall of 2014. Five water crossings were inspected in 2015 and the Phase 1 program was finalized in 2016. Phase 2 of the program commenced in 2017 and is being implemented in 2018/2019.

Pearl City WWPS & Waipahu WWPS Force Main Condition Assessment, Honolulu, HI. TAT reviews and program input for the Condition Assessment. The Pearl City forcemain consisted of 11,500 feet of dual ductile pipes varying in diameter from the 24 to 42 inches. The dual Waipahu WWPS Force Main is approximately 12,600 linear feet in length, ranging in size from 36-inches to 48-inches in diameter. It was primarily constructed of concrete cylinder pipe (CCP), but also included portions of reinforced concrete pipe (RCP), cast iron pipe (CIP) and DIP.

Region of York, YDSS Assessment and Development of Rehabilitation Concepts for the 16th Avenue and 9th Line Trunk Sewers. Senior Technical Specialist for the physical condition assessment and development of viable rehabilitation concepts for of a 2642mm diameter trunk sewer that varied in depth from approximately 35m to 42m through a mature developed urban area with adverse soil and groundwater conditions. Condition assessment technology included the deployment of MSI platforms and post processing of dimensional data with a virtual mandrel to confirm lining requirements/logistics while the rehabilitation program designed to utilize sliplining with GRP liners under live flow conditions. (2013 to 2015)

Sewer Condition Assessment Program for the City of Winnipeg. Sewer inspection consisting of closed circuit video inspection and condition coding in accordance with the Water Research Council's (WRc) standardized codes evolving to NASSCO PACP codes. The condition coding quantitatively describes the structural and service condition as well as the physical construction features of the sewer. Under the program since 1997, 1100 km of combined sewers (100% of the network) and 1425 km of separate sanitary sewers (95% of the network) have been inspected. AECOM has provided contract administration services as well as analytical services related to reviewing the inspection tapes and condition coding, recommending and prioritizing rehabilitation requirements, and recommending and prioritizing specialized maintenance requirements. Details of rehabilitation and maintenance needs, including budget costing, are forwarded to the City for repair by their own forces or private contractors. The program is on-going through 2018.

CHRIS MACEY, PE - CONTINUED

Assessment of the Aubrey Avenue and Yonge Street Tunnel Sewers, Region of York. Physical condition assessment program of two tunnel sewers, 1350 mm and 1650 mm in diameter. Program included concrete coring and assessment, visual assessment, and advanced structural assessment of each sewer. Primary deterioration processes were identified and forecasted and a management strategy was developed to rationalize approach to future rehabilitation and monitoring to preclude unanticipated failure.

Primary Trunk (PT) Sewer Assessment, Region of York. Initial condition assessment of 5 km of critical trunk sewer ranging in diameter from 2550 mm (102") to 3000 mm (120"). The initial condition assessment program involved the development of a FEA applied loads model to assess the pipe's vulnerability to deterioration and an assessment of the primary deterioration processes that the pipe was subjected to. The output of the program is being used to rationalize the most effective field condition assessment program involving the use of mutli-sensor technology, advanced spatial referencing, and both destructive and non-destructive testing to confirm residual material strength.

Multi-Sensor Sewer Inspections – Winnipeg, MB. Deployment of Multi-sensor Sewer Condition Assessment and Data Interpretation for Large Diameter Interceptor Condition Assessment to inspect the North End Interceptor (2010), South End Interceptor (2011), and the North West Interceptor (2012) in Winnipeg, MB utilizing high resolution CCTV imagery, laser scanning, SONAR, and H_2S screening tools. From 2010 through 2012, 85 km of the 115 km long interceptor network will have been inspected and had its condition fully assessed.

Watercare New Zealand – Army Bay WWTP Replacement Outfall. Senior Technical Reviewer for a 900 metre long by 800 mm diameter DR26 HDPE outfall. AECOM was client advisor on this Design-build project of an approximate 800 mm diameter DR26 marine outfall. Responsibilities included review of Marine Outfall Detailed Design Report, including sections pertaining to stability design and installation stress analysis. On same project provided review of Project was completed in August 2018.

City and County of Honolulu, HI – Kailua Outfall Assessment. Senior Technical Lead to develop an inspection plan to assess the structural and service conditions of 6.2 miles of 54-inch steel forcemain and 48-inch reinforced-concrete outfall pipe that conveys treated wastewater effluent from the Kailua Regional WWTP to the Pacific Ocean. Work is to include confined entry inspections of 20 subsurface vaults, in-line video inspections of the forcemain and outfall pipes, and external video inspections of the marine outfall using submersible ROVs.

Capital Region District, McLoughlin Point Wastewater Treatment Plant, Victoria, British Columbia. Senior Technical Specialist for preliminary and detailed design of a 2000 millimetre (80") marine outfall in a design-build delivery for the McLoughlin Point WWTP. Project includes coordination of cathodic protection systems, on-bottom stability analysis, diffuser detailing and alignment/ profile design selection. Project designs utilized Det Norske Veritas (DNV) standards for hydrodynamic on bottom stability and cathodic protection systems. Pipeline consists of approximately 2100 m (1.5 miles) of outfall in depths ranging from 15 m to 60 m, and features "wet exit" MTBM detailing, cut and cover sections for anchor protection, as well as bottom lay segments using concrete weight coating. Detailed design commenced in late 2016. Implementation of the outfall construction is scheduled for 2019.

Condition Assessment of all Buried Pipe at the Piscataway WWT Plant – WSSC – Washington, DC. Senior technical advisor to facilitate a condition assessment program for all buried pipe assets at the plant including the final outfall pipe (108 inch diameter PCCP) which discharges to the Potomac River. Condition assessment program includes the use of both traditional condition assessment techniques and advanced tools (RFTC) to assess the final outfall pipe.

CHRIS MACEY, PE - CONTINUED

Georgia Pacific – St. John's River Outfall - Palatka, FL. Senior Technical Specialist to assess failure cause and design and implement remedial measures to facilitate emergency and permanent repairs for 1325 m of a 1050 mm diameter HDPE wastewater effluent line in the St. Johns River in Palatka, FL. The outfall was from a major pulp and paper mill and assessment included buoyancy and stability analysis as well as corrosion protection for all metallic components.

Publications / Presentations

Books

C.C. Macey and J.S. Lueke - editors (2018), "Pipelines 2018: Utility Engineering, Surveying, and Multidisciplinary Topics", American Society of Civil Engineers (ASCE).
I. Doherty D. Downey, C.C. Macey, K. Rahaim, K. Sarrami, K. Contributing Authors, "NASTT Best Practice Guidelines for CIPP" - 2015

Chris has also authored and/or co-authored over 130 publications/presentations/technical courses including:

1. *"CIPP A North American Perspective: Assessing the Performance of 40 Years of CIPP Lining Rehabilitation in Winnipeg, MB Canada" presented at Water New Zealand Conference & Expo 2018 in September 2018 in Hamilton, NZ*
2. *"Design and Rehabilitation of a 1200 mm (48"), 98 Year old brick sewer at depths of over 21m with CIPP" presented at Water New Zealand Conference & Expo 2018 in September 2018 in Hamilton, NZ*
3. *"Using Probabilistic and Deterministic Modeling Techniques to Relate Funding to Service Levels to Drive a Water Main Rehabilitation Program in Toronto, Canada" published in the proceedings of ASCE Pipelines and presented in July 15-18, 2018 at ASCE Pipelines 2018 in Toronto, ON, Canada*
4. *"North Fork Siphon Condition Evaluation" published in the proceedings of ASCE Pipelines and presented in July 15-18, 2018 at ASCE Pipelines 2018 in Toronto, ON, Canada*
5. *"A Rational Approach to Designing Spray Applied Polymeric Manhole Rehabilitation Products" published in the proceedings of ASCE Pipelines and presented in July 15-18, 2018 at ASCE Pipelines 2018 in Toronto, ON, Canada*
6. *"River Crossing Inspections – Balancing Risk with the Need to Obtain Advanced Pipeline Condition Assessment Data" published in the proceedings of ASCE Pipelines and presented in July 15-18, 2018 at ASCE Pipelines 2018 in Toronto, ON, Canada*
7. *"Condition Assessment and Asset Preservation Rationalization for the St. Paul Regional Water Services (SPRWS) in St. Paul, MN" published in the proceedings of ASCE Pipelines and presented in July 15-18, 2018 at ASCE Pipelines 2018 in Toronto, ON, Canada*
8. *"Competitive Tendering of Alternative Sewer Rehabilitation Technologies for Large Diameter and Non-Circular Applications" published in the proceedings of No-Dig 2018 at Palm Springs, CA and presented on March 27th, 2018.*
9. *"Assessment of the 110 Year Old Sunrise Highway Aqueduct - to Rehabilitate and Repurpose it for use as a 72" Treated Effluent Force Main" published in the proceedings of No-Dig 2018 at Palm Springs, CA and presented on March 26th, 2018.*
10. *"Watermain Renovation Using Structural, Semi-Structural and Non-Structural Lining Systems" presented at UCT Annual International Conference and Exposition on January 30th, 2018, in New Orleans, LA.*
11. *"Assessing the Longevity of PVC Pipe Under Extreme Pressure Loads in Colorado Springs, CO" at the AWWA Water Infrastructure Conference November 30th-November 2nd of 2017 (AWWA Water Infrastructure 2017 in Houston, TX)*
12. *"Critical Force Main Assessments for the City of Raleigh Public Utilities Department (CORPUD)" 97th Annual North Carolina AWWA-WEA Conference, November 13, 2017 in Raleigh, NC*
13. *"Rehabilitating A 155 Year Old Arch Shaped Brick Sewer Under The Ross Bay Cemetery With Glass Reinforced Polymers" published in the proceedings and presented at ASCE Pipelines 2017 in Phoenix, AZ on in August 9th, 2017*
14. *"Looking for Simplified Design Models for Non-Circular Liner Design - Moving Beyond WRc Type II Sewer Design Methodologies for the North American Market" published in the proceedings and presented at ASCE Pipelines 2017 in Phoenix, AZ on in August 8th, 2017*

CHRIS MACEY, PE - CONTINUED

15. *"Using Risk Models and Automated Defect Characterization Algorithms to Convert PACP Data into Capital Upgrading Programs for ALCOSAN" published in the proceedings presented at ASCE Pipelines 2017 in Phoenix, AZ on in August 8th, 2017*
16. *"Introduction to the AWWA M28 Manual (what is in the M28 Manual and what is not!)", a training module for the pre-conference workshop; "Managing Water Main Distribution Systems – from Condition Assessment to Rehabilitation Methods, Economics of Failure and Long Term Planning" and the Annual Conference and Exposition (ACE) 2017 for the American Water Works Association (AWWA) on June 10, 2017*
17. *"Budgeting for Underground Pipe Renewal: Relating Investment $ to Service Levels" presented at the National Water and Wastewater Benchmarking Initiative Summary Workshop in Winnipeg, MB, Canada on April 26, 2017.*
18. *"Design And Rehabilitation Of A 48", 90 Year Old Brick Sewer At Depths Of Up To 70 Feet with CIPP (To Protect It From A 20 Foot Tunnel Being Constructed Right Under It!)" - published in the proceedings of No-Dig 2017 at Washington, DC and presented on April 10th 2017*
19. *"The Challenge of Inspecting 362 Outfalls for Condition Assessment In Winnipeg, MB, Canada" - published in the proceedings of No-Dig 2017 at Washington, DC and presented on April 10th 2017*
20. *"A Brief (Mostly Hydraulic…) History Of The Shoal Lake Aqueduct" presented for the Canadian Water Resources Association (CWRA) on March 15th, 2017 in Winnipeg, MB, Canada*
21. *Five modules for a workshop on Water and Waste Water Pipeline Condition Assessment and Rehabilitation for the Consortium for Engineered Trenchless Technologies (CETT) at the University of Alberta, Edmonton, AB, Canada on February 16th, 2017. The modules included:*
    a. *"Failure Modes and Deterioration Mechanisms for Various Types of Pressure Pipe Materials - Understanding Material Degradation – A Critical Foundation for the Condition Assessment Process"*
    b. *"Risk-based Assessment of Water and Wastewater Pipes"*
    c. *"Scheduling Pipelines for Renewal and/or Subsequent Inspection"*
    d. *"Key Attributes for Water Pipelines Asset Inventory- what should we know about our inventory?"*
    e. *"Case Study Qa for Rehab: Pressure Pipe Rehab with CIPP Products; The quest to build and confirm that we built an AWWA M28 Class IV Liner - A fully structural liner independent of the host pipe"*
22. *"Structural, Semi-Structural, and Non-structural Linings – Advances in Testing Regimens to Facilitate Structural Classification Designations" presented at UCT Annual International Conference and Exposition on February 1, 2017.*
23. *"Engineering Responsibility - The Engineer's Duty of Care…The importance of understanding (and learning from) failure…" presented at the 2017 American Concrete Pipe Association (ACPA) Pipe School in Arlington, TX on January 4th, 2017*
24. *"Condition Assessment of Wastewater Force Main Assets" presented at the 96th Annual North Carolina AWWA-WEA Conference, November 13-16, 2016 in Raleigh, NC*
25. *"From Desktop Studies to the Use of Advanced Tools; Program evolution and the integration of traditional and advanced condition assessment methodologies for Critical Watermains in Regina, SK, Canada" at the AWWA Water Infrastructure Conference in November of 2016 (AWWA Water Infrastructure 2016 in Phoenix, AZ)*
26. *"ALCOSAN Service Area Sewer Regionalization Update" in the proceedings of the 17TH Annual 3 Rivers Wet Weather Sewer Conference in Pittsburgh, PA in October of 2016.*
27. *"External Water Main Deterioration- Using Science in Condition Assessment and Failure Mitigation – Ferrous and Cementitious Materials" – A seminar for the Joint AWWA-WEF NC Chapter on Watermain System Assessment and Rehabilitation on August 2nd and 3rd, 2016 in Raleigh, NC*
28. *"Dealing with the Results of Advanced Inspection Technology – Emergency Rehabilitation of the St. James Interceptor Siphon by CIPP Methods in Winnipeg Manitoba, Canada" presented and published in ASCE Pipelines Proceedings in July of 2016 (ASCE Pipelines 2016 in Kansas City, MO)*
29. *"Large Diameter, Non-Circular Trunk Sewer Rehabilitation using GRP Composites" presented and published in ASCE Pipelines Proceedings in July of 2016 (ASCE Pipelines 2016 in Kansas City, MO)*

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30. *"A Global Perspective on Structural Classification and Testing of CIPP Pressure Liners" presented and published in the Proceedings of the 2016 ACE of the AWWA in June 2016 in Chicago, IL*
31. *"Intelligent Use of MTBM Construction Technology to Minimize Construction Footprint and Mitigate Risk In A Mature Neighborhood With Complex Soils in Calgary, AB, Canada" - presented and in the proceedings of No-Dig 2016 at Dallas, TX in March 2016.*
32. *"Assessing The Performance Of 38 Years Of CIPP Installations In Winnipeg, Manitoba, Canada" - presented and published in the proceedings of No-Dig 2016 at Dallas, TX in March 2016.*
33. *"Watermain Rehabilitation Short Course" – primary course developer and co-delivery of a 2 day course on specialist techniques for watermain rehabilitation for CATT in Mississauga, ON on January 26-27, 2016*
34. *"The Soil Side of Pipe-Soil Structures- Geotechnical Requirements for Rigid and Flexible Pipe Design" – a course for the American Concrete Pipe Association Pipe School in Dallas, TX in January 2016*
35. *"Maintaining and Rehabilitating Watermains" – Development and delivery of a 2 day course on maintenance, condition assessment and specialist rehabilitation technologies for EPIC in Mississauga, ON on November 2-3, 2015*
36. *"NASTT's Cured-in-place pipe (CIPP) – Good Practice Guidelines" – co-author and published by NASTT as their CIPP global best practices publication in July of 2015.*
37. *"Thinking about an AWWA M28 Class IV Liner? A suggested testing regime to verify the manufacture, design and construction processes" in the Proceedings of the 2015 ACE of the AWWA in June 2015 in Anaheim, CA*
38. *"Beyond ASTM F1216; a Proposed Design Protocol for Liners in Pressure Service" in the Proceedings of the 2015 ACE of the AWWA in June 2015 in Anaheim, CA*
39. *"Risk Based Condition Assessment and Rehabilitation Planning for Pressure Pipes" delivered as a Webinar for the ASCE Webinar Series for Online Learning on May 7, 2015*
40. *"Reinforced Concrete Pipe – How To Assess The Transition From Indirect To Direct Design Methods In Deep Cover Installations" in the Proceedings of the 2014 Western Canada Water Conference in Regina, SK in September 2014*
41. *"Screening Tools and Some Leak Detection Lessons" presented at The 2014 Advanced Non-Destructive Wastewater Force Main Condition Assessment Technologies Workshop - Lessons from the Trenches – Good, Bad, & Ugly in Washington, DC; for the WSSC and Peer Consultants Workshop in August 2014*
42. *"Risk Based Condition Assessment And Rehabilitation Planning In Colorado Springs" published in ASCE Pipelines Proceedings in August of 2014*
43. *"Rehabilitation of the Deacon Reservoir Cell 1 and 2 Interconnector Pipes by Sliplining Methods Under Full Reservoir Head" published in ASCE Pipelines Proceedings in August of 2014*
44. *"Initial Condition Assessment of the 3000 mm (120 inch) Diameter Primary Trunk Interceptor for the Region of York" published in ASCE Pipelines Proceedings in August of 2014*
45. *"A Suggested Framework for the Condition Assessment of Pressure Pipelines" presented as part of the Spring 2014 Lecture Series for the University of Cincinnati Post Graduate Engineering Studies in March 2014 in Cincinnati, OH.*
46. *"The importance of understanding (and learning from) failure…"; an Engineering Discernment presented at the 2014 Pipe School for the American Concrete Pipe Association in Houston, TX in February 2014.*
47. *"Rationalizing an Approach and Rehabilitating a 150-yr Brick Storm Drain Inventory in Victoria, BC" presented at the 2013 WCW Conference in Edmonton, AB in September 2013*
48. *"Product Overview and Quality Assurance Ramifications associated with Pressure Liners" presented at the 2013 WCW Conference in Edmonton, AB in September 2013*
49. *"Modelling Deterioration in Local Sewers in Edmonton, AB Using the Markov Model" presented at the 2013 WCW Conference in Edmonton, AB in September 2013*
50. *"Post Installation Repair of Large Diameter Reinforced Concrete Pipe at the Calgary Airport Expansion" presented at the 2013 WCW Conference in Edmonton, AB in September 2013*
51. *"Pressure Pipe Lining Workshop - Practical Design and Implementation Considerations to Make It Work" – A one day workshop in St. Catherine's, ON; in April, 2013*

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52. *"More really old CIPP Liners from Winnipeg, MB, Canada (that have stood the test of time)" presented and in the proceedings of No-Dig 2013 at Sacramento, CA in March 2013.*
53. *"Design Needs for Pressure and Non-Pressure Pipeline Pipelines for Lining Applications" delivered at the Centre for Advancement of Trenchless Technologies (CATT) workshop on Engineering Successful Trenchless Projects on October 12th, 2012.*
54. *"Quality Assurance and Quality Control for Trenchless Lining Applications" delivered at the Centre for Advancement of Trenchless Technologies (CATT) workshop on Engineering Successful Trenchless Projects on October 12th, 2012.*
55. *"The Engineer's Duty of Care…the importance of learning from failure…", Keynote Address for the OCPA 2012 Fall Meetings, Blue Mountain, ON on September 25th, 2012.*
56. *"The History of Cured-in-place-pipe (CIPP) use in Winnipeg, MB – 34 Years of Successful Program Implementation" presented at the 2012 WCWWC in Winnipeg, MB in September 2012.*
57. *"City of Winnipeg Interceptor Inspection Program Challenges & Results" presented at the 2012 WCWWC in Winnipeg, MB in September 2012.*
58. *"Knowing Your Feedermains Through Valve Chamber Condition Assessment" presented at the 2012 WCWWC in Winnipeg, MB in September 2012.*
59. *"Reinforced Concrete Pipe Design under Extreme Loading Conditions using ASCE Standard Practice 15-98 and Beyond…" presented at ASCE Pipelines 2012 Conference in Miami Beach, Florida in August 2012.*
60. *"34 Years Of Quality Assurance Testing For CIPP In Winnipeg, MB, Canada" delivered at No-Dig 2012 in Nashville, Tennessee March 2012*
61. *"Reinforced Concrete Pipe Design – Indirect and Direct Design Concepts and Practical Considerations" and "High Density Polyethylene (HDPE) for Gravity Sewer Applications - Design and Construction Considerations" – course notes for a two day course on Rigid and Flexible Pipe Design for the Canadian Concrete Pipe Association (CCPA) Annual Technical Sessions in Edmonton, AB on November 30 – December 1, 2011.*
62. *"Quality Assurance Program for CIPP in Winnipeg, MB, Canada; 1978-2011" at the Annual Regional Conference for the NorthWest Chapter of NASTT in Calgary, AB, November 17th, 2011*
63. *"Planning A PipeDiver Inspection? Here are some things you should know" at the 2011 WCWWC in Saskatoon, SK, September 21-23, 2011*
64. *"Condition Assessment for Pipelines in Pressure Service" at the 2011 WCWWC in Saskatoon, SK, September 21-23, 2011*
65. *"CFRP Liner Repairs to a Critical PCCP Pipeline in Hamilton; Part A: Liner Design and Procurement", at the 2011 WCWWC in Saskatoon, SK, September 21-23, 2011*
66. *"CFRP Liner Repairs to a Critical PCCP Pipeline in Hamilton; Part B: QA / QC Requirements", at the 2011 WCWWC in Saskatoon, SK, September 21-23, 2011*
67. *"A Framework for Condition Assessment of Pipelines in Pressure Service", at the BCWWA Annual Conference and Trade Show in Kelowna, B.C. on April 18th, 2011.*
68. *"Condition Assessment, Material Degradation, and Rehabilitation", course notes for a Forcemain Systems Design and Assessment Workshop presented in Mount Pleasant, SC, November 5, 2010.*
69. *"Understanding Pipe Deterioration and Failure Causes for Pipes in Pressure Service" presented at WEASC Engineering Workshop "EMERGING TECHNOLOGIES FOR THE INSPECTION OF WATER & WASTEWATER LINES", November 4, 2010 in Columbia, SC*
70. *"Condition Assessment and Rehabilitation Challenges for Forcemains and Gravity Sewer Infrastructure" presented at a Technology Transfer Workshop in Honolulu, Hawaii, October 21st, 2010*
71. *"Equitable Distribution of Risk in Trenchless Underground Rehabilitation Contracts" presented at CATT Trenchless Contracts Specification Workshop, September 28, 2010 in Mississauga, ON*
72. *"Interceptor Inspection and Analytical Assessments Using Multi-Sensor Technologies" presented at the 2010 WCWWC in Calgary, AB, September 23, 2010*
73. *"Draft Guidelines for the Design, Procurement and Construction of Large Diameter Transmission Pipe in the City of Calgary" presented at the 2010 WCWWC in Calgary, AB, September 23, 2010*

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74. *Course Notes for forcemain components of a Design, Operation and Maintenance Workshop for "Wastewater Pumping Station And Forcemain Systems" on January 21 and 22, 2010 in Winnipeg MB for the MWWA & WCWEA*
75. *"Integration of Condition Assessment and other Data into a Hydraulic Modeling Environment" presented at the 2009 WCWWC in Winnipeg, MB, September, 2009*
76. *"Modelling Complex, Multiple Flow Paths Through UV Reactors at the Deacon Booster Pumping Station, Winnipeg, Manitoba" presented at the 2009 WCWWC in Winnipeg, MB, September, 2009*
77. *"Wastewater Storage For Basement Flooding Relief In Saskatoon, Saskatchewan" presented at the 2009 WCWWC in Winnipeg, MB, September, 2009*
78. *"Leveraging Existing Sewer Model Data" presented at the BCWWA Annual Conference and Trade Show– Climates of Change in Whistler, B.C. on April 28th, 2008*
79. *"Geotechnical Information for Trenchless Projects (Lining & Pipe Bursting) - What Information do we need to mitigate unnecessary problems?" presented at CATT symposium on Geotechnical Considerations for Successful Trenchless Technology in Mississauga, ON in November 2007*
80. *"Field Trials of Two Technologies For Detecting Leaks In Wastewater Forcemains" presented at the 2007 WCWWC in Edmonton, AB, October 23-26, 2007*
81. *"Using Opportunistic Sampling to Assess AC Watermain Performance in Winnipeg" presented at the 2007 WCWWC in Edmonton, AB, October 23-26, 2007*
82. *"Time to Renew Your Aging System: What's in your tool box?", co-author of the 2 day AWWA Course on watermain rehabilitation, rationalization of approach, structural and non-structural design concepts, and condition assessment methods for water infrastructure, presented in Seattle, WA on October, 2007 and Philadelphia, PA in February, 2008*
83. *"An Integrated Management Approach for Critical Water Mains" presented at the 2008 ASCE Pipelines Conference in Atlanta, GA*
84. *"A Case for Installing an Anode with Every Repair of a Cast Iron Water Main – Almost" presented at AWWA's ACE in Toronto in June 2007*
85. *"NASTT Cured-in-Place-Pipe Good Practices Course" a technical training course for the NASTT for the City of Atlanta, May 23 and 24, 2007*
86. *"The Development of Deterioration and Sustainability Models for Sewer Infrastructure in the Lower Mainland of B.C." presented at the WEAO 36th Annual Technical Symposium And OPCEA Exhibition in London, ON, on April 17, 2007 and at the BCWWA 2007 Annual Conference & Trade Show in Penticton, BC, April 21-25, 2007*
87. *"A Review of the Technical Feasibility of Alternative Leak Detection Technologies for Wastewater Sewer Forcemains" presented at the 53rd Annual Seminar & Trade Show of the Manitoba Water and Waste Association in Winnipeg, MB, February 19-21, 2007*
88. *"The True Life Cycle Cost of Linear Infrastructure (and Other Related Issues)", Infrastructure Management Conference in Calgary, AB in December 2006.*
89. *"Introduction to CIPP technology – Overview, Applications, and Range", CATT Seminar in Waterloo, ON in November 28, 2006*
90. *"Direct Design of RC Pipe- SIDD Design Requirements and Field Inspection", an instructional course for the Canadian Concrete Pipe Association in Winnipeg, MB, on November 15, 2006*
91. *"The Winnipeg WTP – From Drawing Board to Reality" presented at the 2006 WCWWC in Winnipeg, MB, September 26, 2006*
92. *"Modeling Failure Rates in AC Water Mains Using a Non-Homogeneous Poisson Process" presented at the 2006 WCWWC in Winnipeg, MB, September 25, 2007*
93. *"City of Hamilton's State of the Infrastructure Report" presented at the 2006 WCWWC in Winnipeg, MB, September 25, 2006*
94. *"Using Risk Analysis for the Planning and Prioritization of Water System Needs" presented at the 2006 WCWWC in Winnipeg, MB, September 25, 2006*
95. *"Design and Installation of High Density Polyethylene Pipe in Gravity and Pressure Service for Water and Wastewater Applications", a one day course for the WCWWC in Winnipeg, MB on September 24, 2006*
96. *"Pipeline Rehabilitation using CIPP", a 2 day technical training course for the NASTT delivered for the City of Edmonton, AB, on April 24 and 25, 2006*

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97. *"Standard Practice for the Design & Construction of Gravity Sewer Pipe in the Cities of Edmonton and Calgary" presented at the annual general meeting of the Canadian Concrete Pipe Association on February 17, 2006 in Vancouver, BC*
98. *"Condition Assessment, Asset Management, Capital Planning for Underground Utilities" for URISA GIS and Asset Management Conference, Burnaby, B.C., February 13, 2006*
99. *"High Density Polyethylene (HDPE) for Gravity Sewer Applications - Design and Construction Considerations", Technical Seminar for the City of Edmonton, January 2006*
100. *"Design and Construction of Cured-in-Place Pipe (CIPP) and other pipe liners…" course material for a graduate studies course at the University of Waterloo, ON delivered in July 2005*
101. *"10 Years of Asset Management for Sewer and Water Infrastructure in Winnipeg, MB" presented at CATT's Rehab Roadshow in Niagara Falls, ON, June 2005*
102. *"Design and Construction of CIPP", a technical training course for the NASTT delivered at No-Dig 2005, Orlando, Florida, April 2005*
103. *"The Development of Advanced Asset Deterioration Models and Their Role in Making Better Rehabilitation Decisions" presented at No-Dig 2005, Orlando, Florida, April 2005*
104. *"Watermain Deterioration, Condition Assessment, and Failure Mitigation – an Update" for OGRA/CATT Water Network Trenchless Pipe Assessment and Renewal, April, 2005, Toronto, ON*
105. *"Choosing the Right Sewer Pipe for the Right Application and Making it Work" for GeoPipes 2005, March, 2005, Toronto, ON*
106. *"Determining Sustainable Funding Levels to Address Sewer Deterioration – Winnipeg's Model" delivered at Managing Canada's Civil Infrastructure Assets: Scope, Technologies, Issues, and Opportunities A One-Day Workshop sponsored by the Canadian Society of Civil Engineering in Winnipeg, November 2004.*
107. *"Use Of Performance Criteria For Acceptance Of Drainage Infrastructure - An Edmonton Experience" presented at BC Water & Waste Association 32nd Annual Conference, Whistler, B.C., May 4, 2004*
108. *"Assessment of Exterior Concrete Degradation of the Shoal Lake Aqueduct (Mile 1.16 to Mile 26.32)" at the NACE Northern Area Western Conference, Victoria, BC February 2004*
109. *"Life Cycle Cost (LCC) Considerations- Large Diameter Gravity Pipe Applications" for GeoPipes 2004, February, 2004, Toronto, ON*
110. *"Watermain Deterioration, Condition Assessment, and Failure Mitigation" for OGRA/CATT Water Network Trenchless Pipe Assessment and Renewal, February, 2004, Toronto, ON*
111. *"Watermain Corrosion and Cathodic Protection" - University of Waterloo – CATT Water Network Rehabilitation Workshop, November, 2003*
112. *"Condition Assessment of Sewer and Water Networks in the Overall Asset Management Process" - Water and Sewer Asset Management Seminar CATT at University of Waterloo, October, 2003*
113. *"Transient Considerations and Fatigue Limit Checks for Design of PVC Forcemain – Case Studies from the lower Mainland of B.C."- 2003 WCWWC, October, 2003, Winnipeg, MB*
114. *"Extending SCADA to an 80 Year Old Aqueduct - Shoal Lake Aqueduct Monitoring & Instrumentation" - 2003 WCWWC, October, 2003, Winnipeg, MB*
115. *"Standard Practice for the Design & Construction of Flexible Pipe in the City of Edmonton" - 2003 WCWWC, October, 2003, Winnipeg, MB*
116. *"Using Real Data To Drive a Sustainable Sewer Infrastructure Management Strategy" – a half day seminar presented at TTBC "No-Dig Live 2003" in Vancouver, B.C. in July 2003*
117. *"Sewer Infrastructure Management Process and Support Tools" presented and in the proceedings of Infra 2002, Montreal, Quebec, November 2002*
118. *"Asset Management for Sewer Infrastructure – 4 Years of Implementation in Winnipeg, MB" presented at No-Dig 2002, Montreal, Quebec, April 2002.*
119. *"Corrosion Risks with Underground Watermains" presented at the MaRIMS Seminar to the Manitoba Association of Risk Managers on October 30, 2001.*
120. *"Flexible Pipe Design Seminar - Thermoplastic and Thermosetting Materials", a one-half day seminar on flexible pipe design presented to the City of Edmonton Drainage Branch in January of 2001 and the City of Calgary Drainage Branch in March, 2002.*

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121. *"Trenchless Technologies for Sewer Rehabilitation in the City of Winnipeg" presented at Western Water and Wastewater Conference in Winnipeg in 2000.*
122. *"Hydraulic Assessment of the Shoal Lake Aqueduct" presented at Western Water and Wastewater Conference in Winnipeg in 2000.*
123. *"Asset Management for Sewer Infrastructure in the City of Winnipeg" presented at Western Water and Wastewater Conference in Winnipeg in 2000.*
124. *"Trenchless Technologies for Sewer Rehabilitation in the City of Winnipeg" presented at World Wise '99.*
125. *"Development and Implementation of Drainage Safety Guidelines for the City of Winnipeg presented at World Wise '99.*
126. *"Sewer Management System – Asset Management for Sewer Infrastructure" presented at World Wise '99.*
127. *"Sewer Rehabilitation Design Seminar – Asset Management for our Sewer Infrastructure", a six part seminar on sewer rehabilitation design and the application of asset management principles to the rehabilitation of sewer infrastructure in March 1999 for the City of Winnipeg and all Consultants involved in the City's Sewer Rehabilitation program.*
128. *"City of Winnipeg Drainage Safety Seminars", seven lectures on drainage safety from November 1998 to May 1999 to a broad cross section of Consultants, Contractors, Material suppliers, and City of Winnipeg Water and Waste and Public Works personnel.*
129. *A series of lectures to municipalities in the lower mainland of British Columbia (B.C.) and on Vancouver Island on "Asset Management for Sewer Infrastructure" in September/October of 1998.*
130. *"Sewer Renovation by CIPP Lining Methods - Overview of Planning, Execution, and Qa/Qc Considerations", IRAP Seminar on Trenchless Technologies, January 28, 1998.*
131. *"Assessment and Rehabilitation of the Shoal Lake Aqueduct Pressure Pipe" presented at the 1997 Western Canada Water and Wastewater Conference.*
132. *A series of lectures on "Corrosion Basics and Practical Applications for Cathodic Protection" to City of Winnipeg Operations and Technical Staff, the local Consulting community, and contractors in March and June of 1996.*
133. *"Assessment and Rehabilitation of the Shoal Lake and Branch Aqueduct System", presentation at the American Concrete Institute (ACI) Annual Spring Convention in Denver, Colorado, March 1996.*
134. *"Alternative Piping Systems for Gravity Sewers - Practical Design Considerations", Presented at the 41st Annual Manitoba Water & Wastewater Association Annual Seminar, February, 1995*
135. *"Rehabilitation Techniques for Aging Infrastructure", course notes for a seminar on Trenchless Technology organized by the Technical University of Nova Scotia in September, 1992 in Winnipeg, Manitoba.*
136. *"Alternative Solutions to Deteriorating Sewer Systems", course notes for a seminar on Sewer Rehabilitation organized by the Technical University of Nova Scotia in March, 1992 in Halifax, Nova Scotia.*
137. *"Managing a Northern Water System for Freezing Protection - Town of The Pas, Manitoba" in the Proceedings of the 1991 Western Canada Water and Wastewater Conference.*
138. *"Tylehurst Sewer Relief and Pollution Abatement Studies" in the Proceedings of the 1991 Western Canada Water and Wastewater Conference.*
139. *"Corrosion of Cast Iron Water Distribution Systems" presented at the 1988 Bi-Annual Conference of the Chinese Civil Engineering Society (CCES) in Beijing, People's Republic of China.*
140. *"Aspects of Watermain Corrosion in Rehabilitation Work" in the Proceedings of the 1987 Conference of the International Federation of Municipal Engineers.*
141. *"Rehabilitation of Aging Infrastructure in Northern Manitoba, Flin Flon: A Case Study", September, 1985 in the Proceedings of the 1985 Western Canada and Wastewater Conference.*

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MARSHALL GIBBONS

MATERIALS ASSESSMENT SPECIALIST

Education
Diploma, Civil Engineering Technology, Red River Community College (now Red River College) - 1988
BSc, Geology, University of Manitoba - 1985

Licenses/Registrations
Certified Engineering Technologist - Manitoba

Affiliations
- Certified Technicians and Technologists Association of Manitoba
- NACE International, Member No. 102046
- Water Environment Federation, Member No. 01828713
- Society for Protective Coatings, Member No. 1111153567

Mr. Gibbons is a Senior Materials Specialist with over 20 years' experience in the inspection and assessment of aging water and sewer infrastructure, with the past 15 years being focused on the planning and execution of inspection and assessment programs for municipal piping systems using direct and indirect inspection methods and nondestructive inspection tools. He has considerable knowledge of historic piping materials and construction methods, and he has completed numerous condition investigations and QA/QC inspections on piping systems and facilities constructed of steel, iron, reinforced concrete, PCCP, FRP and other materials. Mr. Gibbons also provides corrosion failure investigation and mitigation design services to projects across North America and is a member of NACE International and SSPC – The Society for Protective Coatings.

PROJECT EXPERIENCE

St. Paul Regional Water Services, St. Paul, MN. – Condition Assessment of Raw Water Supply Pipelines. Served as Inspection Lead for the condition assessment of 27 miles of 36-, 60- and 90-inch riveted and welded steel, reinforced concrete and PCCP pipelines that convey raw water to the McCarrons Treatment Plant. Developed schedules and methodologies for inspecting the pipelines that include visual, CCTV, sounding and ultrasonic inspection, and material testing. Also assisted with the development of confined entry safety and rescue plans.

ArcelorMittal Dofasco, Hamilton, ON – CFRP Repairs to PCCP Pipeline. Developed quality control procedures and performed quality assurance inspections for the installation of carbon-fiber reinforced polymer repairs within a deteriorated 48-inch PCCP cooling water pipeline at a steel manufacturing facility. Also completed condition inspections of the liners at the 6-month and five-year service milestones. Completed the initial internal condition inspections and geospatial surveys of 48- and 54-inch PCCP pipelines to determine the feasibility of relining the pipelines, and assisted the Owner with independent reviews of third-party inspection and engineering assessment reports.

City of Hamilton, ON – Woodward–Greenhill Water Transmission Main Assessment. Inspection Lead and key contributor to the multi-stage inspection and condition assessment of the city's most critical PCCP water transmission main: Four (4) miles of 48-inch through 96-inch PCCP. Investigations included corrosion surveys and environmental characterization studies, external pipeline and subsurface vault inspections, installation of galvanic cathodic protection, and in-line electromagnetic surveys (remote field transformer coupling - RFTC) using Pure Technologies' PipeDiver and crawler/cart-based inspection platforms.

City of Winnipeg, MB – Force Main Condition Assessment. Provided a condition assessment and recommendations for rehabilitation of the 1.5-kilometre (0.9-mile) prestressed concrete cylinder pipe (PCCP) force main that serves the WEWPCC. Investigations included closed-circuit television inspections of the interior of the force main, and visual inspections of the exterior of the force main at test pits and subsurface vaults. Pipe sizes ranged from 450mm (18-inch) through 900mm (36-inch) diameter.

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City of Winnipeg, MB - Feeder Main Valve Chamber Inspection Program, Winnipeg, Manitoba. Assisted with the development of an inspection program and led a team of inspectors in completing confined entry structure and piping condition inspections of 206 subsurface valve chambers located throughout the city's water transmission system.

City of Winnipeg, MB – Butterfly Valves Inspection. Inspected manufacturing facilities and provided quality assurance/quality control (QA/QC) inspection and testing for the acceptance of several 2134 mm (84-inch) and 600 mm (24-inch) butterfly valves destined for the owner's new water treatment plant and points on the water transmission system.

City and County of Honolulu, HI – Kailua Outfall Assessment. Developed an inspection plan to assess the structural and service conditions of 6.2 miles of 54-inch steel force main and 48-inch reinforced-concrete outfall pipe that conveys treated wastewater effluent from the Kailua Regional WWTP to the Pacific Ocean. Work is to include confined entry inspections of 20 subsurface vaults, in-line video inspections of the force main and outfall pipes, and external video inspections of the marine outfall using submersible ROVs.

City of Regina, SK – Water Supply and Feeder Main Condition Assessment. Technical advisor assisted with inspection and condition assessment of the city's inventory of large-diameter steel potable water supply and transmission mains. Selected representative mains for inspection using in-line high-resolution electromagnetic inspection technology (magnetic flux leakage). Performed inspections of valve chambers to evaluate accessibility for inspection tools, and to confirm preliminary pipe information, including pipe and coating materials, diameter, wall thickness (ultrasonic measurement), external condition and cathodic protection. Provided guidance for executing the MFL inspections, and assisted with the review of inspection data to assess the condition of the mains.

Metro Vancouver, BC – Highbury Interceptor Siphon Liner Assessment. Provided preliminary inspection services and implemented a liner inspection methodology to facilitate structural assessment and rehabilitation of a 64-inch diameter CIPP liner installed within Siphon #2 of the Highbury Interceptor crossing beneath the Fraser River. Work included visual and sounding inspections of the entire Siphon #2 liner, extraction of coupons from the liner for laboratory testing, and inspection of polyurethane grout injection activities to seal leaks.

Manitoba Floodway Authority, MB – Seine River Siphon Inspection. Developed inspection and safety plans to enable the physical and structural assessment of a 1200 mm (48-inch) corrugated, high-density polyethylene inverted siphon that conveys the Seine River beneath the Winnipeg Floodway, a seasonal flood diversion channel.

City of Winnipeg, MB – Plessis Road Underpass. Contract Administrator for relocation of three 8- and 10-inch diameter midstream product pipelines at a road/rail grade separation for two global oil companies. Administered separate material supply and pipeline construction contracts that included provision of pipe and induction bends, conventional and trenchless (HDD) installation of mainline pipelines, pipe material testing and identification (PMI and OES testing), development and certification of welding procedures, purging of pipelines to remove product and to install nitrogen blankets, connection of new piping to valve station, installation of new valves, spools and pig launcher within the valve station, and installation and testing of cathodic protection equipment.

City of Winnipeg, MB - River Crossings Condition Assessment. Presently assisting with the inspection of 14 steel water and wastewater river crossings, with sizes ranging from 8-inch through 32-inch. Directly involved in the review and selection of electromagnetic and other pipeline inspection tools, and the development of inspection methodologies for each pipe crossing.

Greater Vancouver Regional District, BC – Lions Gate Secondary Wastewater Treatment Plant Design-Build. Provided technical guidance to the design team regarding methodology for condition inspection of GRP marine outfall pipeline that conveys treated wastewater effluent from the treatment plant to the Strait of Georgia.

MARSHALL GIBBONS - CONTINUED

City of Winnipeg, MB – West End Water Pollution Control Centre Force Main Twinning. Assisted with the design and provided QA inspection during construction for a new 0.9-mile, 24-inch diameter PVC force main serving the treatment plant. QA inspections included inspection of pipe supplier's manufacturing facility and review of manufacturer's QA/QC procedures, including GRP-reinforced fitting fabrication area, and ultrasonic thickness checks of PVC pipe on site. Also assisted with the development of emergency repair protocols for the existing force main rehabilitation program.

Capital Commercial Pipe Services, ON – Quality Assurance Inspections of GRP Liner Segments. Developed inspection methodology and completed QA inspections of 54-inch wide by 65-inch high GRP box liner segments being manufactured for a sewer lining project in Toronto. Included inspections of the liner manufacturing facility and reviews of the manufacturer's quality control procedures, and inspections of stockpiled GRP liner segments.

City of Winnipeg, MB – West End Water Pollution Control Centre Clarifier Dome Inspections. Completed preliminary inspections and provided recommendations for further evaluations and repair of deteriorated protective coatings on GRP domes covering the secondary clarifier tanks.

City of Abbotsford, BC - Steel Pipeline Quality Assurance Inspections. Performed quality assurance inspections for a steel water transmission main being constructed in mountainous terrain. Inspections were focused primarily on the quality of plant- and field-applied coatings being provided to the project, but also included a review of third-party inspection and contract administration services being provided to the owner.

Newport, RI – Cathodic Protection of Pump Station Piping. Designed a galvanic cathodic protection system for pump suction barrels and discharge piping for the New Lawton Water Valley Treatment Plant.

Wabowden, MB - Cathodic Protection Program. Assisted with the field investigation and design phases, and administered the construction of galvanic cathodic protection system for 2.7 kilometres of ductile iron water mains.

City of Winnipeg, MB – River Crossings Assessment Study. Field tested/evaluated relevance of newly-developed Echologics acoustic leak correlator to provide accurate condition assessments of water distribution mains crossing beneath river channels.

City of Hamilton, ON – Water Main Condition Assessment Pilot Study. Developed a field inspection and testing program to evaluate the effectiveness of using the newly-developed Echologics acoustic correlator to provide accurate condition data for cast and ductile iron water mains. Testing was performed in conjunction with the National Research Council of Canada.

City and County of Honolulu, HI – Water Main Failure Analysis. Investigated the root cause of failure of a cast iron water main based on failure history, site soil and corrosion investigations, and laboratory analysis of pipe fragments salvaged from a recent failure. Also provided design and quality assurance reviews for galvanic cathodic protection system installed on a replacement ductile iron water main.

Greater Toronto Airports Authority, ON – Ductile Iron Assessment and Rehabilitation. Provided a condition assessment and designed the rehabilitation of 0.2 mile of 12-inch water main and 16-inch wastewater force main located beneath a major highway interchange, and serving the northeast quarter of the Toronto Pearson International Airport.

City of Winnipeg, MB – Disraeli Water Main Condition Assessment. Completed the condition assessment and provided rehabilitation alternatives for a 20-inch insulated steel water main crossing the Red River beneath the Disraeli Bridge. Investigations included external visual examination of piping beneath the bridge deck and in subsurface vaults, and corrosion close-interval corrosion surveys of buried steel and iron piping approaching the bridge.

Greater Toronto Airports Authority, ON – Water Main Corrosion Study. Field investigation and condition assessment of 8.7 km of drinking and fire water mains servicing the Terminal 2 area of Pearson International Airport.

ROBERT VAIL

CORROSION ENGINEER

Education
BS, Chemical Engineering, Oklahoma State University - 1985

Licenses/Registrations
NACE International Corrosion Specialist (G) #3705
NACE International Cathodic Protection Specialist #3705
NACE International Protective Coatings Specialist #3705
NACE International Certified Coating Inspector #7348

Affiliations
- American Water Works Associations
- NACE International
- American Public Transportation Association
- American Society of Civil Engineers

Mr. Vail has extensive experience in corrosion engineering for pipeline, marine, transit and industrial projects. His work has included: coating selection and specifications; stray current/ corrosion control design and specifications for new construction and rehabilitation of a wide variety of pipelines, shore facilities, plant facilities, storage tanks and, rail transit systems; testing and troubleshooting of existing cathodic protection systems and rail transit system stray current/ corrosion control systems; pipeline integrity management; performing and coordinating coating evaluations and coating application inspections; performing and supervising close-interval surveys and external corrosion direct assessments; dynamic and static stray current evaluations and stray current mitigation designs. Prior to joining AECOM, Mr. Vail was the Staff Corrosion Engineer for the world's largest volume refined petroleum pipeline system.

PROJECT EXPERIENCE

Tarrant Regional Water District, Integrated Pipeline Project, Dallas, TX. Provided QA/QC review of corrosion control and coatings design calculations, design drawings and specifications for construction of a new mortar-lined steel water pipeline ranging in diameter from 90 to 108 inches.

Dallas Water Utilities Department, Southwest 120/96-inch Water Transmission Pipeline Project, Dallas, TX. Providing QA/QC review of impressed current and galvanic cathodic protection system designs, drawings and specifications for prestressed concrete cylinder pipe (PCCP) and coated steel water transmission piping.

Oklahoma City Water Utilities Trust, Atoka Pipeline Project, Oklahoma City, OK. Perform soil corrosivity testing and analysis, cathodic protection system designs, drawings, specifications, construction inspection, and commissioning testing for a new 72-inch steel raw water pipeline system. The corrosion control design includes consideration of stray current interference from existing pipelines and induced AC interference from collocated high voltage power transmission lines.

North Dakota State Water Commission, Southwest Pipeline Project, Mercer County, ND. Providing QA/QC review of corrosion control and coatings design calculations, design drawings and specifications for construction of a new 30-inch diameter mortar-lined steel water pipeline.

Region of Peel, Water and Wastewater Design Guidelines for Stray Current Mitigation, Mississauga, Ontario. Developed an addendum to the design guidelines and standard drawings for water and wastewater infrastructure to address stray current control from DC transit systems.

Orange County Sanitation District, Preparation of Corrosion Control Standards, Fountain Valley, CA. Responsible for preparation and revision of corrosion control standards, specifications, and drawings for a water and wastewater district. Included review of all discipline

ROBERT VAIL - CONTINUED

specifications for materials, coatings and corrosion control issues.

Orange County Sanitation District, Digester Inspection, Fountain Valley, CA. Performed visual inspections and limited physical/chemical testing to evaluate the level of surface preparation and condition of reinforced concrete digesters undergoing rehabilitation for a water and wastewater district. Included review of drawings, surface preparation methodology, specifications for repair materials, coatings, and corrosion inhibitors.

Capital Regional District, McLoughlin Point Wastewater Treatment Plant, Cross-Harbour Force Main, and Outfall, Vancouver, BC. Evaluate internal and external corrosion control requirements for a new horizontal directional drill harbour crossing pipeline and for an outfall pipeline. Evaluation considers corrosivity of transported fluids and external environment, internal and external coating selection and specification. A feasibility analysis of applying cathodic protection was performed. Project also includes complete corrosion control analysis and materials/coating selection for the new wastewater treatment plant.

United States Air Force Academy, Base-Wide Findings and Recommendations for Cathodic Protection, Colorado Springs, CO. Evaluate all underground metallic utilities and non-metallic utilities with metallic fittings to determine the operational status of existing cathodic protection and where cathodic protection is necessary but not presently installed. Included evaluation of the base water pipelines, sewer pipelines and lift stations, culverts, water wells, reservoir dam equipment and conduits, underground storage tanks, aboveground storage tanks, and the wastewater treatment plant. Provided recommendations and cost estimates for corrective repairs or modifications necessary to comply with USAF guidelines. Included cost-benefit analysis of repair versus replacement.

Nuverra Environmental Solutions, Inc., Fracking Water Supply and Disposal, Scottsdale, ND. Provided materials selection recommendations on a project to develop hydraulic models, analyze fracking water supply and disposal operations, estimate maximum pressures, specified sizing and ratings of valves, fittings and booster pump stations, and provided recommendations for the piping system configuration for wastewater disposal and pump stations.

Global Foundries US, Inc., Waste Water Corrosivity Study, Saratoga County, NY. Prepared and executed a study to determine the corrosivity of a wastewater discharge stream from a semi-conductor manufacturing facility to a reinforced concrete pipeline system.

Naval Facilities Engineering Command MIDLANT, Water Tank Replacement Construction Package, MCB Camp Lejeune, NC. Responsible for design, drawings and specifications for impressed current cathodic protection systems for the interior surfaces of 9 elevated potable water storage tanks.

Northeast Ohio Regional Sewer District, Dugway West Interceptor Relief Sewer, Cleveland, OH. Responsible for design review, materials selection and construction method review with respect to corrosion control for the lining of a large diameter rock tunnel combined sewer interceptor system subject to DC transit stray current interference.

Texas Parks & Wildlife Department, Battleship Texas Cathodic Protection System Survey, LaPorte, TX. Performed a survey of an impressed current cathodic protection system for the external hull surface of the Battleship Texas. Determined the operational status of the system, evaluated the effectiveness of cathodic protection and provided recommendations for adjustments and maintenance of the system.

Coastal Protection and Restoration Authority, Coating Inspection of Seabrook Vertical Lift Gate, Orleans Parish, LA. Performed a visual coating inspection of a vertical lift gate constructed by the USACE to determine if the coating finish satisfied contractual requirements, identified surface or film defects in the coating system that could increase risk of structural damage, qualitatively evaluated coating bond strength to the steel structure and intercoat bond strength between coating layers, determined if coating repairs were necessary and to provide general coating repair procedures as applicable.

JAMES JAMEISON, PE

CORROSION ENGINEER

Education
BS, Electrical Engineering, Drexel University - 1975

Licenses/Registrations
Professional Engineer - Minnesota, Virginia, Pennsylvania, North Carolina, New Jersey, Maryland, Delaware
Professional Corrosion Engineer - California
NACE International Corrosion Specialist (P) #3609
NACE International Cathodic Protection Specialist #3609

Affiliations
- NACE International
- Institute of Electrical & Electronics Engineers

Through his work as a consultant for numerous clients, Mr. Jameison has been and is actively involved in projects associated with corrosion control and cathodic protection system design for essentially all types of below- and above-grade facilities. As a consultant, Mr. Jameison has been involved in stray current and general corrosion control for water and gas distribution and transmission systems since 1975. Early in his career, he conducted pre-construction field surveys to evaluate the corrosivity of areas for proposed water and gas piping replacements and prepared reports which presented recommended corrosion control measures to be installed with new piping systems. He also conducted post-construction field tests to verify proper installation of the recommended corrosion control measures and conducted new systems testing which evaluated the effectiveness of the installed corrosion control measures. Since the majority of his work experience was performed in the Philadelphia/ Baltimore/Washington area, where there are DC negative rail return heavy and light rail transit lines, stray current effects were always a consideration. He has conducted area stray traction earth current evaluations on water and gas transmission and distribution systems and on other utility type facilities and structures located in very close proximity to DC powered negative return heavy and light rail transit systems in most major cities across the United States and in Toronto, Canada. This work included conducting field studies and supervising other field crews, data analysis and report preparation, and design of required mitigation and/or protection systems.

Mr. Jameison's other experience includes: evaluation of the effects of induced AC potentials on structures in close proximity to high voltage power transmission lines; design of AC mitigation systems to maintain safe conditions along the affected structure; evaluation of static charge effects associated with the discharge of petroleum products into tanks; design of static abatement systems to preclude the generation of significant static potential charges and still maintain effective cathodic protection of the tank(s) and associated piping; evaluation of electrical power grounding systems from determining the integrity of the existing ground system to the design of a suitable ground grid/network; conducting and being responsible for corrosion control field investigations for water, gas, steam, wastewater and POL piping systems and ocean outfall lines; design of corrosion control systems for below- and above-grade facilities including pipelines, bridge/building foundation structures, underground tanks and piping systems; coordinating over the line, close interval surveys on several large diameter water transmission mains; design of cathodic protection systems for tanks, pipelines, elevator cylinders, dock structures and building foundation systems; testing for and the design of stray current mitigation systems for both utility and transit facilities; testing and troubleshooting DC negative return and positive power distribution systems relative to maintaining effective electrical isolation from earth; evaluation of the effectiveness of protective coating systems on tanks and pipelines and in locating areas of coating defects on below-grade piping networks; and non-destructive testing (NDT) ranging from obtaining the field data to statistical analyses of data collected by others.

JAMES JAMEISON, PE - CONTINUED

He has been involved in NDT on above- and below-grade pipelines, as well as, above- and below-grade storage tanks. He has also been involved in External Corrosion Direct Assessment surveys for numerous high-pressure transmission mains located in defined High Consequence Areas.

PROJECT EXPERIENCE

South Central Light Rail Transit Extension Project, Phoenix, AZ. Presently, Mr. Jameison is the Engineer of Record relative to stray current and corrosion control for the subject project. The project is an approximate 6-mile extension to the existing LRT route and will extend LRT service to the south from downtown Phoenix to Baseline Road. The project includes installation of 11 passenger stations, installation of the LRT system across two existing aerial structures, and a maintenance and storage facility. Mr. Jameison is responsible for the design of stray current corrosion control mitigation and monitoring systems for all transit-fixed facilities and for new/relocated utility facilities.

Southwest Light Rail Transit Project, Minneapolis, MN. Presently, Mr. Jameison is the Engineer of Record relative to stray current and corrosion control for the subject project. The project is an approximate 14.5-mile extension to the existing Central Corridor LRT route and will serve the growing communities of Minneapolis, St. Louis Park, Hopkins, Minnetonka and Eden Prairie. The project includes installation of 15 passenger stations, numerous aerial transit structures, two transit tunnels, and a maintenance and storage facility. Mr. Jameison is responsible for the design of stray current corrosion control mitigation and monitoring systems for all transit-fixed facilities and for new/relocated utility facilities.

Dulles Metro Rail Project Extension to Wiehle Avenue. The project consisted of a 11.7-mile, 5-station extension to the WMATA heavy rail transit system in Vienna, VA. The consultant Mr. Jameison worked for was retained as the corrosion control/stray current corrosion control design engineering firm, and Mr. Jameison was the Engineer of Record for the design of all stray current corrosion control systems installed on transit-fixed facilities and for the design of cathodic protection systems installed with new/replacement, buried, pressurized, ferrous piping systems. Mr. Jameison's company was also retained as part of the project's construction team and he was responsible for overseeing the engineering crews performing pre-pour/backfill and post-pour/backfill acceptance tests on all stray current corrosion control facilities installed on the project. He was also responsible for preparation and submittal of the pre- and post-construction test reports.

STV - LYNX Light Rail in Charlotte, NC - Blue Line Extension. The project consists of a 9.3-mile, 11-station extension to the light rail transit line. The consultant Mr. Jameison worked for was retained as the corrosion control/stray current corrosion control design engineering firm, and Mr. Jameison was the Engineer of Record for the design of all stray current corrosion control systems installed on transit-fixed facilities and for the design of cathodic protection systems installed with new/replacement, buried, pressurized, ferrous piping systems. He was also responsible for overseeing contractor construction submittals to assure that the materials to be installed were in compliance with the project specifications and to review contractor post-installation test data to assure that the installed special corrosion control measures were installed in a satisfactory manner.

Houston Metro. Mr. Jameison was the Project Manager for two annual contracts with Houston Metro to perform annual stray current surveys along various sections of their light rail transit system. The data obtained during the annual surveys is compared to data obtained during previous annual surveys to determine if stray current levels have increased along the transit system. Increased stray current levels on transit test locations would indicate a possible loss of electrical isolation of the DC negative return system, which could result in increased corrosive stray current effects on both transit owned facilities and nearby utility facilities. Mr. Jameison was responsible for overseeing the field crews obtaining the field data and analysis of all collected data. He was also responsible for preparation and submittal of a written report. Facilities tested during the annual tests included track slab test stations, test stations on area water mains, and test stations on nearby reinforced concrete bridge structures.

JAMES JAMEISON, PE - CONTINUED

Mr. Jameison is recognized as one of the leading corrosion control stray current experts in the United States. He has conducted corrosion control design studies for proposed and existing transit facilities in North and South America. He has also conducted computer-aided network analysis to determine anticipated stray current levels along the transit line and on nearby utility facilities. Mr. Jameison has conducted initial design studies in regard to anticipated stray currents and track-to-earth potentials for the following transit systems:

- Dulles Extension, Vienna, VA (WMATA/MWAA)
- San Juan, Puerto Rico (GMAEC Tren Urbano Project)
- Sacramento, CA (Sacramento Transit Development Agency)
- Caracas, Venezuela (Metro de Caracas)
- Boston, MA (Southwest Corridor Reconstruction Project)
- Toronto, Canada (Scarborough Light Rail Transit System)
- San Diego, CA (San Diego Trolley)

He has been involved in stray current analysis on the following transit systems:

- Dulles Extension to Wiehle Ave., Vienna, VA (WMATA/MWAA)
- Houston Metro
- King County Metro - Sound Transit
- Kenosha Streetcar, Kenosha Area Transit (KAT)
- San Juan, Puerto Rico, GMAEC Tren Urbano
- Dallas, TX, Dallas Area Rapid Transit (DART)
- Cleveland, OH, Regional Transit Authority (RTA)
- Philadelphia, PA, Southeastern Pennsylvania Transit Authority (SEPTA)
- Camden, NJ, Port Authority Transit Corporation (PATCO)
- San Francisco, CA, Bay Area Rapid Transit District (BART)
- Atlanta, GA, Metropolitan Atlanta Rapid Transit Authority (MARTA)
- Toronto, Canada, Toronto Transit Commission (TTC)
- New York City, Long Island Railroad
- Long Beach, Los Angeles, CA
- Baltimore, MD, Maryland Mass Transit Administration (MTA)
- New York City, Metro-North Railroad
- Buffalo, NY, Niagara Frontier Transportation Authority

THOMAS DEGEN, PE
TECHNICAL ASSISTANCE

Education
BS, Civil Engineering, University of Wisconsin, Platteville - 1983

Licenses/Registrations
Professional Engineer - Wisconsin

Affiliations
- American Water Works Association
- Wisconsin Rural Water Association
- Society of Water Professionals

Mr. Degen has more than 30 years of experience with a variety of potable water projects; and he has led many condition assessment and asset management projects. Through the management of SPRWS's Water Main Risk-Based Prioritization Project, Mr. Degen gained an understanding of the SPRWS work process and their project team.

PROJECT EXPERIENCE

DuPage Water Commission, Water Mains Condition Assessment, Chicago, IL. Managed the task of performing a risk-based condition assessment of water mains for the DuPage Water Commission. Using historical data and GIS data, developed a water main replacement privatization process based on risk factors, including the probability of failure and the consequence of failure for each pipe segment. Developed scoring processes using surrogate condition indicators. Used Weibull Function statistical methods to forecast replacement dates; and prepared an annual forecast of replacement and pipe condition assessment funding requirements.

Saint Paul Regional Water Services, Water Distribution Level of Service and Reinvestment, Saint Paul, MN. Project manager for the development of a risk-based approach for the prioritization of the replacement/ rehabilitation of water mains. Established capital improvement plan for the replacement of water mains to lower risk of failure.

City of Appleton, Water System Master Plan, Appleton, WI. Project manager for a water distribution master plan study to provide city with a prioritized capital improvements plan designed to support growing customer demands in a cost-effective way. The study was designed to address the city's key issues, including proactive water main replacement program using KANEW software, water quality and turnover in storage tanks, compliance with Disinfectant By-Product Stage 2 Rule, system pressures/pressure zone boundaries, service to wholesale customers, and creation of a calibrated extended period simulation model integrated with existing and future GIS.

City of Janesville, Water System Master Plan, Janesville, WI. Project manager for a water distribution master plan study to evaluate distribution system capacity, supply adequacy, future water supply, vulnerability of supply to nitrate and radium contamination, potential well sites, energy efficiency, water main replacement prioritization as well as asset management, workforce staffing, system controls and system operations.

City of Ann Arbor, Water Distribution Level of Service and Reinvestment, Ann Arbor, MI. Assisted with the development of Key Performance Indicators and service levels. Responsible for using the KPIs and service levels to establish a reinvestment strategy for the water system using a risk-based approach.

West Virginia-American Water, Rate Case Testimony Assistance, Charleston, WV. Project manager for testimony and assistance in connection with the filing of the client's current water rate case with West Virginia Public Service Commission. Project manager for the review of main break history and

THOMAS DEGEN, PE - CONTINUED

evaluation of break history, condition assessment of the infrastructure facilities, preparation of a reinvestment capital plan and development (risk-based) of a leakage management strategy.

Joint Base Elmendorf – Fort Richardson, Infrastructure Assessment Non-Privatized Systems, Elmendorf AFB and Fort Richardson, AK. Deputy project manager and water team leader for the project to assess infrastructure systems, which included airfield pavements, electrical, water, wastewater, storm water, roadway pavements and bridges. Field verified existing system data, survey locations, system element condition, and the linear segment condition. Created robust data system layers in GeoBase. Developed asset management tools to allow quantitative evaluation of replacement and improvement projects to maintain infrastructure systems based on risk associated with asset condition and criticality.

US Air Combat Command, ECAS - Drinking Water Asset Inventories, Condition Assessments, and Management, Offutt AFB, NE; and Langley AFB, VA. Project manager for developing an accurate inventory of water assets to enhance productivity and operating efficient systems that supply, treat, store and transport water. Developed and pilot tested a risk-based tool for managing the water infrastructure, which includes pipes, valves, hydrants, pump stations, tanks, reservoirs and control valves. Integrated the tool with legacy data sources. The project also included developing a water audit following AWWA Manual M36, and updating GIS mapping and associated data domains and metadata associated with the water system.

Sustainable Infrastructure Assessment, US Air Force, Various Locations. Water systems team lead for component inventory and condition surveys of all building, mechanical, electrical, lighting, energy and water systems at 23 Air Force bases throughout the US and Europe. Oversaw development of tablet application used by the assessment teams conducting building assessments and equipment bar coding.

City of Mankato, Water Treatment Plant Expansion, Mankato, MN. Assisted with the design and construction-related services associated with the expansion of the treatment plant from 6.0 to 12.0 MGD, which included replacing the existing conventional granular media filters with new ultrafilter membranes, two new solid contact clarifiers for lime softening, expanded clearwell and high-lift pumping, new horizontal collector well, new screened well, two road improvements, raw water transmission main, and new storage reservoir.

Town of Greenville, Water System Master Plan, Greenville, WI. Project manager for a review of the town's water system and preparing a water system master plan to meet the increasing demands. Managing service area planning, water needs analysis, hydraulic model development, deficiency analysis, improvement planning, and preparation of a study report.

Sheboygan Water Utility, Water System Evaluation, Sheboygan, WI. Managed a project to update and recalibrate the 1996 water system computer model and perform hydraulic analysis of the water system to evaluate system storage and hydraulic capacity of transmission mains to the expanding southwest high-level pressure zone. Water system demands were projected based on predicted expansion areas and zoning designations. Evaluated options to supply and store water in the southwest zone and in the entire water system to meet the peak requirements. Recommendations included an additional storage tank and improvements to the distribution system between the treatment plant and the southwest zone.

ANDREW ROMER, PE

PIPELINES TECHNICAL PRACTICE LEADER – AMERICAS

Education
BS, Civil Engineering, University of Arizona, 1979
BS, Business Administration, University of Arizona, 1974

Licenses/Registrations
Professional Engineer, Civil - California
Professional Engineer, Civil - Ohio
Professional Engineer - Nevada
Professional Engineer, Civil - Alaska
Professional Engineer, Civil - Utah
Professional Engineer - Florida
Professional Engineer, Civil - Arizona
Professional Engineer - North Dakota

Areas of Expertise
Water Transmission Pipelines
Tunneling
Trenchless Installations
Pumping Stations
Force Mains
Treatment Plants

Affiliations
- American Water Works Association, Pipeline Safety and Risk Management Committee, Pipeline Design Manual Committee and Pressure Pipeline Design for Water and Wastewater Committee
- American Society of Civil Engineers, Pipeline Safety and Risk Management Committee, Pipeline Design Manual Committee and Pressure Pipeline Design for Water and Wastewater Committee
- American Welding Society

Mr. Romer has a total of 39 years of experience, 31 of which have been with AECOM. He has been responsible for design of more than $1 billion in major water transmission pipelines and associated facilities, pumping stations, treatment plants, tunnels, and trenchless installations. Mr. Romer has designed award-winning and innovative large diameter reclaimed waterlines, trunk sewers, outfalls, and force mains. He is a well-published author and is active on national standards committees. His contributions were acknowledged in 2012 with the Stephen D. Bechtel Pipeline Engineering Award by the American Society of Civil Engineers. As AECOM's Pipelines Technical Practice Leader, Mr. Romer provides Quality Control reviews and functions as a Project Advisor to a significant number of AECOM projects throughout North America.

PROJECT EXPERIENCE

Water Transmission Mains & Penstocks

Engineer-of-Record, North Dakota State Water Commission, Raw Water Main Transmission Pipeline Upgrades – Intake to Zap Reservoirs for the Southwest Pipeline Project, Bismarck, ND. Prepared System Improvement Plan and subsequent selection of alignment and design of 19,000 linear feet of 30-inch 301psi (max) steel pipeline (Contract 2-1B). The project is under construction.

ANDREW ROMER, PE - CONTINUED

Project Technical Advisor, Metro Vancouver, Second Narrows Water Supply Tunnel Project, Vancouver, BC. Advisor for the surface works associated with a new water supply tunnel under Burrard Inlet including alternative alignments to accommodate three (3) water mains (2 x 2400mm and 1x 1500mm diameter) complete with shafts and valve chambers downstream of the shafts prior to connection into the existing water system (Capilano No 7, Seymour 2 and Seymour 5). The design criteria requires the system to withstand a 1:10,000 year seismic event. The surface works design package includes the tie-ins, piping, valve design and equipment selections and valve chambers at both the north and south shaft locations.

Project Technical Advisor and Quality Control Reviewer, Peter Kiewit Infrastructure Co, New Post Creek Hydroelectric Project - Peter Sutherland Sr. Generating Station (G.S.), Ontario, Canada. Reviewer and advisor for the penstock. The project is currently under construction and includes a 28 MW hydro power plant, with a 400 m intake canal, a penstock more than 300 m long, a 65 m head, a spillway with a 300 m3/s capacity, an embankment dam and tailrace structures close to 1,000 m long. *Construction: 2015 – Present.*

Technical Advisor, Central Utah Water Conservancy District, Siphon Condition Assessment and Replacement, Orem, UT. Completed an independent evaluation and inspection of 1.4 km (0.9 miles) of an 1800 mm (72-inch) prestressed-concrete inverted-siphon pipeline crossing a river valley in northeastern Utah, with recommendations for rehabilitation of any deteriorated pipe segments identified. AECOM then designed the North Fork Siphon Replacement. When constructed, the Siphon will be an approximately 4,800-feet-long, 84-inch diameter steel water line, traversing a narrow valley, while covering a 716 feet vertical elevation change from inlet to the valley floor on an approximately 70 degree slope. The preliminary design included a pipeline alignment analysis accounting for wetlands, geology, slope characteristics, and existing utilities.

Lead Design Engineer and Engineer-of-Record, North Dakota State Water Commission, Supplementary Intake from Lake Sakakawea for the Southwest Pipeline Project, Bismarck, ND. Responsible for design of a 154 foot-deep shaft, 2,714-foot-long intake pipe, and screen structure for new raw water intake on Lake Sakakawea for the Southwest Pipeline project. *Construction: 2013 – Present.*

Project Manager and Design Lead/Engineer-of-Record, Los Angeles Department of Water and Power, River Supply Conduit Improvement, Units 5 and 6, Los Angeles, CA. Led the design of the 78-inch-diameter steel pipelines within North Hollywood, California. Unit 5 is approximately 3,900 feet in length, of which approximately 3,700 feet is tunneled. Unit 6 is approximately 11,500 feet in length, with approximately half tunneled. Design also included 78-inch butterfly valves and valve vaults, appurtenances, jacked casings, access manholes, asphalt concrete (AC) pavement replacement, walkways, curb and gutters replacements, several utilities relocations, and landscaping.

Design Lead, Cachuma Operation and Maintenance Board, Upper Reach Reliability – South Coast Conduit, Santa Barbara, CA. Designed the 48-inch- diameter steel pipeline through steep terrain, approximately 8,300 feet in length.

Engineer-of-Record, Nipomo Community Services District, Supplemental Water Project, Santa Maria, CA. Responsible for design of the Santa Maria River Crossing. The Supplemental Water Project is designed to transport up to 3,000 acre-feet-per year of water from the City of Santa Maria to the NCSD, and also includes selection of alignments for more than 27,000 linear feet of waterline, a 500,000 gallon reservoir, a 2,000 gpm pump station, and chloramination facilities. The Supplemental Water Project Bid Package #1 includes installation of more than 2,000 linear feet of 24-inch-diameter waterline constructed by multiple pass Horizontal Directional Drilling (HDD) using a mid-path intercept installation for the pilot bore. Located in and across the Santa Maria River, the project was conducted amid sensitive habitats.

Project Manager and Engineer-of-Record, San Luis Obispo County Flood Control & Water Conservation District, Nacimiento Water Pipeline Project, San Luis Obispo, CA. Selection of alignment and design of 45 miles of pipeline ranging in size from 36-inch-diameter down to 12-inch-diameter to convey up to 17,500 acre-feet per year of untreated water from Lake Nacimiento as far south as San Luis Obispo. The work included HDD crossings of the Nacimiento River, US-101 freeway, and Salinas River. Ultimately, the project will deliver 15,750 acre-feet per year of raw water from Nacimiento Reservoir to turnouts serving the growing communities of Paso Robles, Atascadero, Templeton, San Luis Obispo and others. Additional services included establishing a basis of design; performing steady-state and transient hydraulics analyses; developing

ANDREW ROMER, PE - CONTINUED

environmental program compliance plans; assisting in the acquisition of permits; preparing traffic management/control plans; closely coordinating pipeline design with other project consultants; and, developing a GIS model. *This project was a national finalist for the ASCE 2012 OPAL Award.*

Design Lead, Kern County Water Agency, Cross Valley Canal Expansion, Bakersfield, CA. Responsible for design of 132-inch-diameter RCP siphons for the expansion of the Cross Valley Canal. The canal delivers raw water from the California Aqueduct to six local agencies in the county.

Project Engineer, City of Fresno, Raw Water Pipeline, Fresno, CA. Responsible for the design of a 5-mile-long, 60-inch-diameter raw water pipeline between the Friant-Kern Canal and the City of Fresno Surface Water Treatment Facility. The project included flow control facilities and additional appurtenances and structures for draining the pipeline. Performed computerized hydraulic and transient analysis, prepared PS&E for the pipeline, specialized large diameter pipeline appurtenances and connection details to the treatment plant.

Senior Advisor, Colorado Springs Utilities, South Catamount Transfer Pipeline, Colorado Springs, CO. Advisor for the design-build (with Garney Construction) of a 36-inch-diameter (Ductile Iron Pipe Size) DR11 high density polyethylene (HDPE) pipe which was floated across and sunk within the South Catamount Reservoir, a part of the City's Blue River Pipeline. The total length of HDPE placed beneath the reservoir was 2,450 feet.

Project Manager and Engineer-of-Record, Southern Nevada Water Agency, East Valley Lateral Project, Las Vegas, NV. Led the design and construction of the 170-A pipeline and Rainbow Gardens weir. The 170-A pipeline is a 78-inch-diameter mortar-lined, tape-wrapped, and mortar-coated steel potable water pipeline, approximately 44,000-feet-long, as well as a deep-tunneled crossing of the Las Vegas Wash approximately 1,440-feet-long, with shafts approximately 110-feet-deep. The project also includes connections to active water facilities, isolation valves and vaults, and fiber-optic conduit.

Project Engineer, Inland Empire Utilities Agency, Edison Avenue Regional Recycled Water Pipeline, Chino, CA. Responsible for the design of approximately 33,000 feet of 30-inch-diameter recycled water transmission main to interconnect the TP-1 Outfall and the Carbon Canyon Water Reclamation Plant. AECOM identified an alternative alignment that will allow the pipeline to be constructed within unpaved areas instead of Edison Avenue. The realignment also avoided an expensive crossing at Euclid and Edison in favor of a more cost-effective crossing further south. Project responsibilities included utility research, street centerline and pipe alignment, utilities coordination, horizontal and vertical design of pipeline, permitting with California Department of Transportation, Ontario, and Chino, and meetings with the client and stakeholders (including the Cities of Ontario and Chino)

Design Lead, Basin Electric Power Cooperative, Antelope Valley System, Mandan, ND. Design Lead for design of 7.2 miles of 42-inch-diameter pipeline to replace a PCCP raw waterline that had experienced four failures. The project was completed in two construction seasons and placed into service in 2006. [In cooperation with Bartlett & West Engineers]

Technical Consultant, Los Angeles Department of Water and Power, Stone Canyon Water Quality Improvement Project – Lake Bottom Pipeline Installation, Los Angeles, CA. Served as a subconsultant to the pipeline installation contractor, Underwater Resources, for design review and engineering calculations in support of installation of nearly one mile of 63-inch-diameter high density polyethylene (HDPE) pipeline. The pipe was floated on and then submerged along the length and within Stone Canyon Reservoir at depths in excess 100 feet.

Project Engineer and Engineer-of-Record, Los Angeles Department of Water and Power, Owens Lake Project Phase 1 Transmission Mains, Inyo County, CA. Responsible for design of 4.7 miles of 60-inch-diameter welded steel main conveyance pipeline; 66,119 lineal feet of 42-inch-diameter pipeline; 8,599 lineal feet of 48-inch-diameter pipeline; and 3,476 lineal feet of 30-inch-diameter fiberglass pressure pipe. The work was located in one of the most aggressive environments in the world. As project engineer, formulated project options, alignments, costs, and was responsible for final design for the design-build team. Provided construction support services. *2003 ACEC Honor Award.*

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Project Engineer, Kern County Water Agency, Northwest Feeder and Treated Water Pumping Station, Bakersfield, CA. Engineer for the northwest feeder treated water pumping station and pipeline, and provided preliminary and final engineering for 6.5 miles of 30- to 48-inch-diameter transmission pipeline. Pump station includes four, 14 cfs (800 hp) variable frequency drive equipped can-mounted pumping units, including one standby unit. Pump station has a design flowrate of 70 cfs at a total dynamic head of 204 feet. Facilities included a 3,200 cubic foot air chamber for surge control as well as a 12-foot-diameter partially-buried standpipe for surge control upstream of the pumps.

Lead Design Engineer, Cachuma Operation and Maintenance Board, South Coast Conduit (SCC), Santa Barbara, CA. Led the design of the inline valves along the SCC while keeping the pipeline in service by the use of line stops in conjunction with bypass piping. The pipeline is approximately 50 years old and consists of 27- to 36-inch-diameter prestressed concrete cylinder pipe (PCCP), with only one isolation valve. No redundant pipeline exists for conveyance of water when the southern reach of the SCC needs to be isolated for repair.

Quality Control and Project Advisor, City of Greeley, Chimney Park Pipeline, Greeley, CO. Advisor for pipeline design of a 60-inch-diameter water pipeline. The pipeline length is more than two miles. Special designs included crossing both the Great Western Railroad and the Cache La Poudre River.

Project Engineer, Las Vegas Valley Water District, Tropical Zone North 2538 Pipeline, Las Vegas, NV. Project Engineer for preliminary and final design of 3,000 linear feet of 60-inch-diameter steel pipe and 150 feet of 36-inch-diameter pipeline in realigned Tropical Parkway. To accommodate roadway construction, team prepared final design of pipeline in less than three months from notice to proceed. Provided construction support services.

Lead Design Engineer and Engineer-of-Record, Central Utah Water Conservancy District, Central Utah Project, Diamond Fork Pipeline, Orem, UT. Responsible for design of 7.1 miles of 96-inch-diameter AWWA C200 welded steel pipeline. Established design criteria, selected pipe materials, linings and coatings, and engineered pipeline appurtenances. Included were four river crossings and a 1,000-foot-long, 12-foot-diameter steel rib and timber lagging supported tunnel under USH 89/6 and the Southern Pacific (D&RGW) Railroad. Realignments developed during design phase eliminated these costly features and the need for a wetlands crossing. Provided construction support services. *This project won the Consulting Engineers Council of Utah 1998 Engineering Excellence Honor Award.*

Lead Design Engineer and Engineer-of-Record, Central Utah Water Conservancy District, East Juab Water Efficiency Main Pipeline, Nephi, UT. Responsible for design of 3.06 miles of 60-inch-diameter AWWA C200 welded steel pipeline. Established design criteria, selected pipe materials, linings, and coatings; and engineered pipeline appurtenances. The project included a tunnel under the Union Pacific Railroad. Provided construction support services.

Lead Design Engineer, Central Utah Water Conservancy District, Red Hollow Pipeline and Diamond Fork Siphon, Orem, UT. Responsible for design of 3.5 miles of 96- and 114-inch-diameter AWWA C200 welded steel pipelines. Established design criteria, selected pipe materials and linings and coatings, and engineered pipeline appurtenances. Included was design of manifolds to a 300-cfs pressure-reducing station at 440 psi. *This project won the Consulting Engineers Council of Utah 1998 Engineering Excellence Honor Award.*

Design Lead and Engineer-of-Record, San Diego County Water Authority, Pipeline 4B, San Diego County, CA. Responsible for selection of alignment and final design of 3,440 feet of 109-inch-diameter and 44,000 feet of 96-inch-diameter AWWA C200 welded steel water transmission mains. The tunneled crossings of three major arterials included a 12-foot-diameter steel rib and timber lagging supported tunnel under Interstate 15. Engineered relocations and reconnections of PCCP Pipelines 3 and 4 at Red Cedar Drive and at SR-52, which included two 60-inch butterfly valves in vaults. Eighteen connections to existing PCCP pipelines included 10 that were 72 inches or greater in diameter. Construction phase services included direction of inspection of pipe fabrication in eight separate facilities, shop drawing review, and field design changes.

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Design Lead, Washington Suburban Sanitary Commission, W-80.15 Steel Water Transmission Main, Laurel, MD. Responsible for design of 11,000 feet of 96-inch-diameter AWWA C200 water transmission mains, 630 feet of interconnecting 36-inch-diameter AWWA C151 ductile iron pipeline, a pressure-reducing station, and appurtenances. Included were three 12-foot-diameter steel liner plate supported tunnels (one 200-feet-long under Amtrak's 3-track northeast corridor at Lanham Station, one 645-feet-long under I-68, and one 150-feet-long under Maryland Route 504) and two in-line 72-inch-diameter butterfly valves and vaults. Construction phase services included shop drawing review and field design changes.

Design Lead, Washington Suburban Sanitary Commission, W-80.04 and W-81.04 Steel Water Transmission Mains, Laurel, MD. Responsible for design of 16,200 feet of 84-inch-diameter AWWA C200 steel water transmission main, 890 feet of AWWA C151 ductile iron pipe, a pressure-reducing station and appurtenances, an in-line 72-inch-diameter butterfly valve, and two 11-foot-diameter steel liner plate supported tunnels (one 300 feet long under I-95 and one 200 feet long under Maryland Route 202). The projects totaling $20 million are part of a $200 million regional water supply project. Construction phase services included shop drawing review and field design changes.

Project Engineer, Las Vegas Valley Water District, Contract No. 769 - 2635 Zone South Pumping Station Discharge Pipeline, Las Vegas, NV. Responsible for the design of more than 1,000 feet of 90-inch-diameter tunnel and 17,300 linear feet of 72-inch-diameter pipeline and 22,130 linear feet of 66-inch-diameter AWWA C200 welded steel pipeline. Established design criteria, selected pipe materials, linings and coatings, and pipeline appurtenance designs. Included are in-line butterfly valve and vaults every 1/2 mile, turnouts, and connections to existing pipelines. Provided construction support services.

Project Engineer, North Dakota State Water Commission, Devils Lake Emergency Outlet, Bismarck, ND. Engineer for the design of approximately 8 miles of 48- and 54-inch steel pipeline as part of a 300-cfs conveyance system that will take water out of Devils Lake and ultimately release it into the Sheyenne River.

Project Engineer and Technical Advisor, North Dakota State Water Commission, Devils Lake East End Outlet, Devils Lake, ND. Provided engineering services for 27,000 feet of 96-inch-diameter pipeline, five 900-1,500 horsepower vertical turbine can pumps, and numerous large-diameter isolation and surge suppression valves for this 230 MGD raw water emergency conveyance system, which involved three material pre-purchase contracts.

Project Engineer, City of Riverside, North Orange Well Field Blending Water Transmission Mains, Riverside, CA. Participated in preliminary and final design of 10,481 feet of 60-inch welded steel water pipeline, with valve vaults and 72-inch-diameter connections to Linden-Evans Reservoir. Also responsible for design of 8,540 lineal feet of 30-inch pipeline (welded steel pipe and ductile-iron pipe alternatives).

Design Lead, Upper San Gabriel Valley Metropolitan Water District, Reclaimed Water System Pipeline, CA. Preliminary and final design of 3.5 miles of 36-inch-diameter pipeline, a 1,700-hp reclaimed water pumping station, and connections to County Sanitation Districts of Los Angeles County's chlorine contact chamber. Established design criteria, selected final alignment in the river levee, selected pipe materials (AWWA C200 welded steel and AWWA C151 ductile iron), linings and coatings, and engineered pipeline appurtenances. Included were two river crossings and five outlet structures into the San Gabriel River. Designed an additional two miles of 36-inch-diameter pipeline in June of 2014.

Design Lead, Mojave Water Agency, Morongo Basin Pipeline, CA. Established design criteria, selected alignment, pipe materials, linings and coatings, and pipeline appurtenance designs for 6.85 miles of 54-inch-diameter and 62.3 miles of 30-inch-diameter pipeline. The 54-inch-diameter pipe was AWWA C303 concrete cylinder pipe with pressures to 300 psi, and the 30-inch-diameter pipe was AWWA C200 welded steel with design pressures to 400 psi. AWWA C151 ductile iron pipe was a bid alternative to these materials. Included was a crossing of the Mojave River and two pumping stations. Provided construction support services. *This project received the Orange County Engineering Council 1994 Engineering Project Achievement Award – Honorable Mention.*

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Project Engineer, West Basin Municipal Water District, Water Recycling Program - Phase 2, El Segundo, CA. As project engineer, responsibilities for the four construction contracts totaling $33.4 million included establishment of design criteria, selection of pipe materials and linings and coatings, final pipeline and pipeline appurtenance designs, and provision of construction phase services. A 51,267-foot-long 42-inch-diameter pipeline was designed to transport reclaimed water to a reverse osmosis plant. The plant reverse osmosis products are discharged through 5,700 feet of 24- and 30-inch pipeline designed to withstand the aggressive water. 1,000 lineal feet of pile-supported pipe across an abandoned landfill included an 82-foot 10-inch long bridge. Provided construction support services.

Design Lead, West Basin Municipal Water District, Secondary Effluent Force Main, El Segundo, CA. This innovative water recycling project was at the time of construction the largest of its kind in North America. It includes approximately 18,000 feet each of 60-inch-diameter PVC lined AWWA C300 reinforced concrete pressure pipe secondary effluent pipeline, 30-inch-diameter AWWA C151 ductile iron reclaimed water pipeline, 18-inch-diameter HDPE brine pipeline, and 1,613 feet of 48-inch-diameter AWWA C303 concrete cylinder pipe Title 22 reclaimed water pipeline. Five steel casing supported tunnels were designed under major arterials. Responsibilities included establishment of design criteria; selection of pipe materials, linings and coatings, and pipeline appurtenance designs; and provision of construction phase services.

Design Lead, City of San Jose, South Bay Water Recycling Program, Reach SJ-2, San Jose, CA. The Coyote/Old Oakland Road segment of the water recycling project included approximately 33,400 feet of 54-inch-diameter to 24-inch-diameter Title 22 reclaimed water pipeline. Tunnels engineered were under US-101 and nine railroad lines including the double tracked San Jose light rail system and the Southern Pacific. Responsibilities included selection of pipeline alignments; establishment of design criteria; evaluation of alternatives including a bridge over US-101; and selection of pipe materials, linings and coatings, and pipeline appurtenance designs. Provided construction support services.

Design Lead, Anchorage Water and Wastewater Utility, Anchorage Loop Transmission Main, Phase II, AK. In association with another consultant, established design criteria and selected pipe materials, linings and coatings, and pipeline appurtenance designs. The 9,214-foot-long, 48-inch-diameter pipeline through discontinuous permafrost included AWWA C303 concrete cylinder pipe, AWWA C200 welded steel pipe, and AWWA C515 ductile iron pipe as bid alternative materials. Provided construction support services. [In association with Tryck Nyman Hayes, Inc.]

Project Engineer, Elsinore Valley Municipal Water District, Temescal Valley Project Waterline Phase III, Corona, CA. As project engineer, established design criteria and selected pipe materials and linings and coatings. Responsible for pipeline and pipeline appurtenance designs. The 13,000-foot-long 24- and 48-inch-diameter pipeline through the streets of Corona, California, included 350-psi design pressure AWWA C200 welded steel pipe and AWWA C151 ductile-iron pipe as bid alternative materials.

Project Engineer, Municipal Water District of Orange County, AMP S2-S3 Parallel Steel Water Transmission Main, Orange County, CA. Project included 18,600 feet of 66-inch-diameter AWWA C200 welded steel water transmission main. Responsibilities included design of two connections to existing Allen-McColloch Pipeline, two 54-inch-diameter in-line butterfly valve vaults, and addition of a 54-inch-diameter in-line butterfly valve vault to the Allen-McColloch Pipeline. Responsible for design of AWWA C301 prestressed concrete cylinder pipe alternative. Construction phase services included review of shop drawings and direction of inspection of pipe fabrication.

Project Engineer, City of Orlando, South Service Area Reuse Pipeline, Orlando, FL. Developed AWWA C200 welded steel pipe design for 17,000 feet of 30- and 36-inch-diameter reclaimed water pipeline as a bid alternative material to AWWA C151 ductile-iron pipe. Provided construction support services.

Project Engineer, Orange County Water District, Santiago Creek Replenishment Pipeline, Orange County, CA. Services included redesign, shop drawing review, construction review, and direction of in-plant inspection of pipe fabrication, lining, and coating for this 24,775-foot-long, 66-inch-diameter AWWA C200 welded steel pipeline.

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Project Engineer, Anne Arundel County, Fort Meade-Glen Burnie Interconnect Pipeline, Anne Arundel County, MD. Participated in an alignment study, design criteria, and quality control review of design of 4 miles of 36-inch-diameter high-pressure water transmission pipeline. Managed principal design subconsultant, WATEK Engineering Corp., and provided construction support services.

Project Advisor, City of Ann Arbor, Water Main Replacement Prioritization Model, Ann Arbor, MI. Participated in a project for the City of Ann Arbor to develop a formalized, sustainable Level of Service for their water distribution system. The city wanted to advance their capital planning process by identifying critical water distribution system infrastructure and establishing a priority/timing for its replacement or rehabilitation. Through risk exposure based capital planning funds can be spent on the assets with the greatest probability and/or consequence of failure. This helps to control the risk of unexpected costs by reducing the probability of sudden, and potentially, costly water main failure. As part of this project, a Capital Planning Tool was developed that integrates with the city's ArcGIS system. Underlying this model is a tremendous about of data such as remaining useful life, leaks & breaks, pressure, corrosion, C-value, headloss, velocity, soil type, customer complaints, critical and large users, land-use, diameter, and flow. As this data was developed, the City and AECOM established internal City approaches for maintaining data quality as staff collect new data. The developed Capital Planning Tool was developed in a manner to facilitate future adjustment because risk exposure based capital planning is not meant to be a single snap-shot for the City, but rather an ongoing planning approach.

Pumping Stations and Treatment Plants

Design Engineer, Municipal Water District of Orange County, 560-cfs Diemer Booster Pumping Station, Orange County, CA. Services provided for this booster pumping station included design of ASME BPV Section VIII plant piping, 84- and 114-inch-diameter AWWA C200 welded steel pipe interconnections to existing pipelines, 96-inch-diameter suction, and 114-inch-diameter discharge pipelines (Five 1000HP pumps).

Design Engineer, Municipal Water District of Orange County, 154-cfs South County Pumping Station, AMP Flow Augmentation, and Interconnecting Pipelines, Orange County, CA. Participated in preliminary and final design and construction administration for a 66-inch-diameter AWWA C200 welded steel interconnection pipelines between the Allen-McColloch and Santa Margarita pipelines. Included was a 66-inch-diameter in-line butterfly valve vault for the Allen-McColloch Pipeline, a 48-inch-diameter ball valve vault and 154-cfs pumping station with seven 1500HP turbine pumps and pumping station process piping. The project included an adjacent 2-MG buried forebay and surge suppression system. Construction phase services included shop drawing review and direction of in-plant inspection of pipe fabrication. *This project received the Orange County Engineering Council 1993 Engineering Project Achievement Award.*

Project Engineer, Southern Nevada Water Authority, 473-cfs River Mountains Pumping Station, Las Vegas, NV. Engineered 96-inch-diameter AWWA C200 welded steel pipelines between reservoir and the forebay, 108-inch-diameter discharge header inside the pumping station, and 108-inch discharge pipelines, in addition to piping for six (5 initially installed) 3,500-hp pumps. Provided construction support services.

Project Engineer, Southern Nevada Water Authority, 217-cfs Foothills Pumping Station, Las Vegas, NV. Engineered 72- and 96-inch-diameter AWWA C200 welded steel inlet pipelines and 54- and 72-inch discharge pipelines. Included were surge tanks and the pumping station process piping (Seven 2500HP pumps). Provided construction support services.

Project Engineer, City of Orlando, Eastern Regional Water Treatment Plant, Contract No. 2, Orlando, FL. Developed AWWA C200 welded steel pipe design for process and distribution piping in sizes to 54 inches in diameter as a bid alternative material to AWWA C151 ductile iron pipe. The WSP was the contractor-selected material for the plant. Provided construction support services.

Project Manager, Anne Arundel County Department of Public Works, Arnold Water Treatment Plant Expansion, Anne Arundel County, MD. Project manager of principal design subconsultant, WATEK Engineering Corp., for final design and construction phase services for an 8-mgd water treatment plant and support facilities. The project also included a 3.6-mgd water well, piping, offices, laboratory, and control room. Sludge thickening chemical feed systems and automatic controls were also part of the design.

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Pipeline Relocations

Project Engineer, Orange County Water District (OCSD), Relocation of 72-inch Pipeline, Orange County, CA. The OCWD maintains a 72-inch pipeline located approximately 15 feet south of the existing Orangethorpe Avenue right of way, west of Miller Street, adjacent to the Miller Retarding Basin, and within Orange County Flood Control property. Relocation of a portion of OCWD's 72-in pipeline interfered with a grade separation project and was relocated. The work included approximately 700 linear feet of new 72-inch steel pipeline to be constructed 14 feet south of the existing pipeline while protecting the existing pipeline in place and in operation. The work also includes construction of two steel casings underneath the Carbon Canyon and Atwood Channels. Multi-agency and interdisciplinary coordination included engineering a 42-inch-diameter OCSD trunk line into triple-27-inch barrel pipeline under the waterline.

Design Lead, San Diego County Water Authority, Relocation of PCCP Pipeline 3 at SR 125/94 Interchange, San Diego County, CA. Participated in preliminary and final design of 1,664 feet of 72-inch water pipe in two tunnels under a major freeway interchange. This $5.8 million project included portals in congested business and residential areas, connections to PCCP pipelines, traffic control, utility relocations, permitting, and environmental studies. As project engineer, formulated project options, alignments, costs, and was responsible for final design in two separate bid packages. Provided construction support services.

Project Engineer, San Diego County Water Authority, Relocation of PCCP Pipelines 3 and 4 at Bradley Park in San Marcos, San Diego County, CA. Participated in preliminary and final design of 1,653 feet of the 72-inch-diameter Pipeline 3 and 1,533 feet of the 96-inch-diameter Pipeline 4 to move the pipelines from a landfill. This $9,753,000 project included connections to steel pipelines, traffic control, utility relocations, abandonment of existing pipelines, permitting and environmental studies. As project engineer, formulated project options, alignments and costs. Also responsible for final design.

Project Engineer, City of Long Beach, Relocation of 36-inch Water Pipeline, Long Beach, CA. Relocation of pipeline was designed in two weeks in order to incorporate plans in contract drawings of County Sanitation Districts' construction of a 66-inch-diameter trunk sewer. The project required coordination of two different agencies' specification formats.

Project Engineer Municipal Water District of Orange County, Relocation of Tri-Cities Pipeline, Orange County, CA. Construction of the San Joaquin Hills Toll Road at Alicia Parkway required relocation of the 42-inch-diameter Tri-Cities Pipeline. Coordination of conflicting construction sequences and design of temporary services dictated criteria of 600 lineal feet of welded steel pipeline including unique connections to the existing system. Provided construction support services.

Project Engineer, Irvine Ranch Water District, Relocation San Joaquin Reservoir Pipeline, CA. Responsible for establishing design criteria and final design of 24-inch-diameter AWWA C200 welded steel pipe for a maximum pressure of 250 psi. A 1,467-lineal-foot portion of the total 5,000-lineal-foot relocation was within the MacArthur Road Bridge constructed for the San Joaquin Hills Toll Road. Design was to California Department of Transportation's standards and was approved by Caltrans. Provided construction support services.

Project Engineer, Moulton Niguel Water District, Pipelines Relocation, CA. Approximately 500 lineal feet of the total 2,000-lineal-foot relocation of two 20-inch-diameter pipelines was within a new bridge constructed for the San Joaquin Hills Toll Road. A new parallel 12-inch-diameter AWWA C200 welded steel reclaimed water pipeline was also designed as part of the project.

Project Engineer, City of Huntington Beach Water Department, Adams Avenue Bridge Waterline Relocation, Huntington Beach, CA. A buried 24-inch-diameter waterline crossing under the Santa Ana River was relocated on hangers suspended between webs of the existing bridge as part of the US Army Corps of Engineers flood control project. Design of this all-stainless-steel project was to California Department of Transportation's design standards and the UBC Zone 4 seismic provisions.

Project Engineer, Irvine Ranch Water District, Irvine Lake Pipeline Emergency Relocation, CA. Lateral scour due to near record flooding washed out the Irvine Lake Pipeline, prompting emergency design of 30-inch-diameter AWWA C200 welded steel pipe. Coordination of pipe manufacture and installation allowed pipeline to be back in service within one week of flood subsidence.

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Project Engineer, Colorado River Commission, Las Vegas Lateral Relocation Tunnel, NV. The USBR-designed 90-inch-diameter pipeline was exposed due to severe erosion of the Las Vegas Wash. Participated in the $12 million project to replace the exposed pipeline by placement of 2,291 feet of 90-inch cement-mortar lined and coated welded steel pipe within 18- and 32-foot-diameter shafts and a 15-foot-diameter tunnel. Services included construction review, review of shop drawings, and the fabrication of the large diameter pipeline, specials, lining, and coating.

Trunk Sewer and Outfalls

Assistant Project Manager, Orange County Sanitation District, 3-64 Western Regional Sewers Rehabilitation, Orange County, CA. Project 3-64 is a rehabilitation and reconstruction where necessary the entire lengths of the Orange Western Sub-Trunk, the Los Alamitos Sub-Trunk, the Westside Relief Interceptor, and the Seal Beach Boulevard Interceptor. The OCSD's 2006 Strategic Plan Update identified these trunk sewers as deficient from a capacity perspective. As the Assistant Project Manager, prepared and edited the four design memoranda, supervised preparation of the 30% preliminary drawings indicating the replacement/relining recommendations, and evaluated the trunk sewer and manhole conditions/assessments. (2017)

Technical Expert, San Francisco Public Utilities Commission (SFPUC), Collection System Condition Assessment Program, San Francisco, CA. Technical Expert for SFPUC's Sewer System Improvement Program Collection System Condition Assessment Program. This program developed a methodology and long-term condition assessment plan for large collection system assets, including tunnels, large pipelines, interceptor boxes and combined sewer discharge structures. Work included piloting inspection techniques (person-entry, robotic inspection and desktop evaluation). The project also included inspection, structural evaluation and development of conceptual alternatives for rehabilitation of a severely deteriorated 9-foot box sewer in San Francisco's busy downtown area.

Project Engineer, Long Beach Water Department, Naples Sewer Lift Station S-10 Sewer Force Main, Long Beach, CA. The LBWD requested on-site engineering services from AECOM. This work was executed as part of AECOM's on-call engineering services agreement with the LBWD. The work requested includes the on-site visit and discussions with LBWD Engineering staff, preparation of an alignment and profile, and memorandum to address the sewer force main (SFM) failure. The force main segment of concern is located in the City of Long Beach within North Ravenna Drive between the Rivo Alto Canal and Campo Walk. At this general location a SFM rupture has apparently occurred; the exact location of the rupture is unknown. As project engineer prepared the report and was responsible for managing the project budget, schedule, and review of existing utilities. (2014)

Technical Expert, Miami-Dade County, Government Cut and Fisherman's Channel 54-inch Force Main and 20-inch Water Main Relocation, Miami-Dade County, FL. Responsible for the design criteria package which included 1100 linear feet of 72-inch Steel Casing with 54-inch FRMP (MT); 85-foot-deep shafts; 36-inch bypass and line tops; 970 linear feet of 60-inch steel casing with 24-inch ductile iron carrier (MT); 90-foot-deep shafts; and flow meter.

Miami-Dade Water and Sewer Department, Miami Avenue 48-inch FM, Lead Technical Advisor and Quality Manger for 13,000 linear of 48-inch PCECP Force Main, 5,000 linear feet of 12-inch Water Main Improvements, 1000 linear feet of 24-inch drainage, and 72-inch Jack and bore crossing along Miami Avenue, NW 2nd Avenue, and NW 1st Avenue, between NE 36th and 8th Street Responsible for all utility design, MOT, permitting, and construction management for the accelerated project involving City of Miami, FDOT, MD-PWD, and the stakeholders of Wynwood, Design District, and Mid-Town.

Miami-Dade Water and Sewer Department. Design Criteria for Norris Cut Force Main Relocation, Miami FL. Technical Advisor for the development of design criteria and specifications for 5300 linear feet of tunnel and the associated technical requirements for the pipe that included 5300 linear ft. of 60-inch carrier FRMP and 2700 linear ft. of open cut PCECP.

Miami-Dade Water and Sewer Department, 72-inch PCCP Redundant Main at Preston WTP, Miami Florida. Project Technical Advisor for the design and construction of 1200 linear feet of 72-inch PCECP main along West 2nd Avenue, between 11th and 13th Streets, and the associated water, sewer, and drainage relocations.

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The project entailed four complex (4) interconnections to an existing active Interpace-era pipe with provisions for mitigating risks and contingency plans.

Project Manager, City of San Jose, Phase VI of the Interceptor Sewer System, San Jose, CA. Provided project management and design for the sewer interceptor system, consisting of replacement and realignment of approximately 4,500 linear feet of 60-inch-diameter brick interceptor sewer with a new 84-inch interceptor sewer between Structure G located at North Fourth Street and Commercial Street and Structure E located at Zanker Road and Old Bayshore Freeway. Includes innovative tunnel crossing of US-101 freeway.

Technical Lead, Orange County Sanitation District, Bushard Trunk Sewer Project, Orange County, CA. The 108-inch-diameter sewer is one of the major trunk sewer lines discharging to the Orange County Sanitation District's Treatment Plant No. 2 in Huntington Beach. AECOM planned and designed approximately 21,000 linear feet of this sewer utilizing 108-inch-diameter lined reinforced concrete pipe. As a consultant, was brought into the $30M project during the construction phase after the contractor encountered problems assembling the pipe. Provided guidance to the District through arbitration and settlement, and the re-bidding of the pipe supply contract and successful completion of the project. (Design: 2002 – Construction: 2003-2004)

Project Engineer, International Boundary and Water Commission, 144-Inch-Diameter South Bay Land Outfall, San Diego, CA. Designed and provided construction phase services for a 12,400-foot-long, 144-inch-diameter PVC-lined AWWA C300 reinforced concrete pressure pipe sewer that is part of an international effort to intercept and treat flows of raw sewage originating in Tijuana, Mexico, which contaminate San Diego Bay. Construction phase services included shop drawing review and field design changes. *Project received the 1992 San Diego Section ASCE Outstanding Civil Engineering Project Award.*

Project Engineer, City of Modesto, 9th Street Storm Drain, Modesto, CA. Design engineer for approximately 7,500 feet of cast-in-place concrete pipeline ranging in size from 72 to 102 inches in diameter.

Project Engineer, City of San Diego, Tunnel Design Alternative for Morena Boulevard Trunk Sewer, San Diego, CA. Selected alignment and **d**eveloped tunnel design for a 72-inch-diameter PVC-lined sewer avoiding costly surface disruption. The 3,395 lineal feet of 9-foot-diameter tunnel was constructed with steel ribs and timber lagging from two headings, then the 72-inch-diameter ASTM C655 RCP was grouted within using CLSM. Construction phase services included shop drawing review and field design changes. *Project received San Diego Section ASCE Outstanding Civil Engineering Project Award for 1993.*

Design Manager, City of San Diego, Rose Canyon Trunk Sewer, San Diego, CA. Responsible for design of 23,300 linear feet of dual-purpose 60-inch-diameter AWWA C300 reinforced concrete pressure pipe pipeline, six major junction structures, and a 244-foot-long, 3-span PVC-lined steel pipe bridge across Rose Creek. Six earth pressure balance tunnels were engineered including two under the Santa Fe railroad and two up to 1,665 feet in length under major freeway interchanges. This innovative gravity sewer is designed to be convertible after minor cleaning to a 165-psi pressure pipeline for conveyance of reclaimed water. The project also included 1,960 feet of 54- to 72-inch-diameter gravity ASTM C655 RCP sewer. Construction phase services. *Project received the San Diego Section ASCE Outstanding Civil Engineering Project Award for 1996.*

Project Engineer, City of San Diego, Penasquitos Trunk Sewer, San Diego, CA. Responsible for design of 48-inch inside diameter 100-foot-long, 3-span bridge across the Santa Fe Railway's main line. The bridge superstructure is PVC-lined welded steel pipe, with intermediate steel bents aligned with the parallel Miramar Road Bridge. Design was to railroad design standards and the UBC Zone 4 seismic provisions. Provided construction support services.

Project Engineer, Santa Ana Watershed Project Authority, Santa Ana Regional Interceptor Contract 6A Tunnel, CA. Prepared specifications and constructability reviews for 2,000 feet of horseshoe-shaped hard rock tunnel. Tunnel was constructed for installation of a 48-inch-diameter PVC lined RCP interceptor sewer, which was backfilled with controlled low strength cellular concrete.

Technical Leader, Santa Ana Watershed Project Authority, Temescal Valley Regional Interceptor Reach 1, Temescal Valley, CA. As project technical leader, prepared designs for PVC and HDPE alternatives for 28,545 feet of industrial and non-recyclable waste force main. *The project won the Orange County Engineering Council 2002 Engineering Project Achievement Award.*

ANDREW ROMER, PE - CONTINUED

Project Engineer, Clark County Sanitation Districts, Crosstown Interceptor and Relief Sewers, Clark County, NV. Prepared plans and specifications for four material alternatives for 6,500 feet of 39-inch-diameter sewer. Microtunneling was specified for approximately 3,200 linear feet at depths exceeding 40 feet. Value engineering reduced the diameter to 36 inches, and the four alternatives were re-engineered.

Lead Design Engineer, City of Salt Lake City, Raw Sewage Force Main – Salt Lake City Water Reclamation Plant, Salt Lake City, UT. Provided design and construction administration for 4,055 LF of concrete and HDPE raw sewage force main piping located at the Salt Lake City Water Reclamation Plant. The scope of work included direct bury of 1,375 LF of 48- inch diameter PVC lined reinforced concrete pipe, and 2,680 LF of slip lining existing 36-inch and 60-inch cast iron and storm drain piping with new 28-inch and 54-inch HDPE piping. This project also included steel pipe specials, piping appurtenances, new access manholes, 24-inch valves, valve vaults, and demolition and rehabilitation to existing facilities. Total construction cost (completed in 2003) of the project was approximately $2,200,000.

Pipeline Evaluation and Rehabilitation

Project Advisor, Central Utah Water Conservancy District (CUWCD), Inspection of the North Fork Siphon of the Strawberry Aqueduct, Salt Lake City, UT. Project Advisor and analysis for inspection of 78-inch-diameter siphon. The horizontal station length is approximately 4,375 feet but the actual lay length of the siphon is approximately 4,750 feet because of the steep (70%) slopes. The siphon consists of 233 Prestressed Concrete Cylinder Pipe (PCCP) segments. Assisted in the planning phase and in the analysis of the inspection findings, and prepared recommendations to CUWCD.

Project Manager and Design Lead, Metropolitan Water District of Southern California, Etiwanda Pipeline Lining Failure, Los Angeles, CA. Evaluated the causes of the failure of the lining and proposed remedial action. The pipeline is a 144-inch-diameter steel conduit, approximately 5.3 miles in length.

Consultant, US Army Corps of Engineers, Los Angeles District, Chula Vista Sewer Failure, Santa Cruz County, AZ. As subconsultant, evaluated a 36-inch-diameter gravity sanitary sewer recently installed as part of the Chula Vista flood control project. Recommended abandonment in place and construction of a new sewer on a different alignment. [Subconsultant to AMEC-Geomatrix Consultants]

Project Engineer, Cachuma Operations and Maintenance Board, South Coast Conduit Structural Analysis, Santa Barbara, CA. Participated in reliability studies for the Upper Reach and Carpinteria Reaches of a 50-year-old pipeline. Conducted hydraulic, structural, field inspections for this critical aqueduct serving Goleta, Santa Barbara, Montecito, and Carpinteria, California. Conducted structural analyses, surge hydraulic and surge analyses, inspections, and right-of-way analyses of 60-inch RCPP and 30- to 36-inch-diameter segments of the 26-mile-long, 50-year-old aqueduct, in order to determine the remaining useful structural capacity and establish parameters for increasing its capacity.

Lead Design Engineer, Basin Electric Power Cooperative and North Dakota State Water Commission, Coteau Mine Haul Road Crossing, Bismarck, ND. Evaluated effects of proposed operation of 1.3-million-pound dragline and 200-ton capacity coal haulers across 42-inch PCCP and 36-inch steel pipelines. Design of bridge slab protection was honored by North Dakota Council of Engineering Companies 2002 Excellence Award.

Project Engineer, Various Clients, Alignment and Preliminary Design Studies, Various Cities, CA. Participated in the study of the 108-inch-diameter Pipeline 6 for San Diego County Water Authority, the Bear River pipeline alignment study for Salt Lake County Water Conservancy District, the San Gorgonio Pass water importation project for the San Gorgonio Pass Water Agency, and four studies for the long-term reliability of the South Coast conduit for the Cachuma Operations and Maintenance Board.

Project Engineer, Central Iron County Water Conservancy District, Water Delivery Supplemental Analysis, Cedar City, UT. Project engineer for the study to evaluate the feasibility of supplying Cedar City with 10,000 to 20,000 acre-feet of water per year from Lake Powell. One option is to increase the capacity of the Lake Powell pipeline and extend the pipeline to the area. An alternative is to construct a pipeline along an alternative alignment north of Zion National Park. This feasibility level of project costs provided Iron County residents with information on the financial impact on taxes and water rates.

ANDREW ROMER, PE - CONTINUED

Project Engineer, Washington County Water Conservancy District, Supplemental Analysis of the Hurricane Cliffs, the Cockscomb, and Alternate Alignments, UT. The study provided detailed construction costs for specific alignment options including open cut, tunneling, hydropower facilities, and reservoirs for alternative alignments at the Hurricane Cliffs and a pumping station, open cut, and tunneling at the Cockscomb. In addition to the detailed construction costs at these locations, the overall project cost was updated from previous studies conducted since 1995.

Project Engineer, Metropolitan Water District of Southern California, Westside Conveyance Feasibility Study, Simi Valley, CA. Evaluated alternative alignments through the Simi Valley and through the Santa Clara River Valley to supply water through up to 23 miles of 96-inch-diameter pipeline to Calleguas MWD and Las Virgenes MWD. Tunnel alignments through the Santa Susana Mountains were evaluated for geologic risks including landslide, subsidence due to oil pumping, and seismic risk.

Project Engineer, Municipal Water District of Orange County and Santiago Aqueduct Commission, Eastern Transportation Corridor Crossings, Los Angeles, CA. Evaluated effects of proposed toll road construction on parallel MWDOC and SAC facilities including the 54-inch-diameter Allen-McColloch pipeline, the 66-inch-diameter AWWA C200 Allen-McColloch parallel reach S2-S3 pipeline, and the 39-inch-diameter AWWA C303 Baker pipeline. The study led to relocation of the proposed toll road, and ultimately crossing these lifelines with bridges.

Project Engineer, US Bureau of Reclamation, Yuma Mesa Conduit Integrity and Capacity Study, Yuma, AZ. Project engineer for the 3-phase study that included internal inspection of 14.1 miles of RCP conduit up to 60 inches in diameter, hydraulic and structural analyses, and investigation of cleaning and rehabilitation methods.

Project Engineer, Santa Clara Valley Water District, 60-Inch-Diameter PCCP Central Pipeline Structural Analysis, Upland, CA. Internal inspection by the RFEC/TC method indicated 20 pipes with significant wire breaks. As subconsultant, analyzed those pipes and determined the remaining useful structural capacity. [Subconsultant to M.J. Schiff & Associates, Inc. (Upland, California)]

Project Engineer, Washington Suburban Sanitary Commission, Project W-80, Water Transmission Main Replacement, Laurel, MD. Analyzed a failed 84-inch-diameter PCCP pipeline and determined it had negligible remaining service life. Subsequently, designed 5,400 feet of 84-inch-diameter steel water transmission main and an in-line 72-inch-diameter butterfly valve that was constructed on the same alignment.

Project Manager, San Diego County Water Authority, PCCP Aqueduct Capacity, San Diego, CA. Analyzed existing parallel 66, 72-, and 96-inch-diameter PCCP aqueducts for external loading capacity. Established parameters for contract documents and monitoring during construction to avoid overloading pipelines during construction of a parallel aqueduct.

Project Manager, San Diego County Water Authority, Floated Pipe Analysis, San Diego, CA. Analyzed 2,200 feet of the 108-inch-diameter pipeline 5E, which had floated in the trench because of flooding due to El Nino rains. Pipe which was already welded-in-place was determined to have yielded during the two flood events and was recommended for removal, additional inspection, and rehabilitation prior to final placement along original profile. [Subconsultant to PCL Civil Constructors, Inc.]

Project Engineer, City of Signal Hill, Orange Avenue Water Pipeline, Signal Hill, CA. Video inspection revealed extensive deterioration of the 55-year-old pipeline, and cement-mortar lining was recommended. Alternatives to rehabilitation of the 18-inch-diameter steel water pipeline included partial and complete replacement.

Project Engineer, City of Alamagordo, Bonito Pipeline, Alamagordo, NM. Evaluated rehabilitation options for the 74.6-mile-long pipeline. Sections of this 50-year-old CCP pipeline will ultimately be replaced as a result of this study.

Project Engineer, City of Ventura, Reconstruction of Rose Avenue over US 101, Ventura, CA. Evaluated effect of fills proposed for reconstruction of a 42-inch-diameter CCP pipeline originally constructed in 1955. Analysis determined the need to replace the affected portions with new steel pipe.

ANDREW ROMER, PE - CONTINUED

Project Engineer, City of Oxnard, 45-inch CCP Pipeline Evaluation, Oxnard, CA. Evaluated effect of fills placed by a land developer over a city-owned 45-inch-diameter CCP pipeline. Internal inspection indicated cracking due to settlement across an ancient creek bed. Deflection analysis determined the need to remediate the cracks as a temporary measure and relocate the affected portions with new steel pipe.

Project Engineer, Shell Oil Company, Crude Oil Pipeline Analysis, Ventura, CA. Analyzed a suspended 8-inch-diameter crude oil pipeline. Field review revealed broken suspenders, which raised suspicions about the integrity of the pipeline prior to its annual FERC hydrotest. Analyses were completed to determine the most practical means of supporting the pipeline without imposing additional stresses.

Project Engineer, Anne Arundel County, Failure Investigation, Emergency Rehabilitation Designs, and Design of Replacements for Force Mains, Anne Arundel County, MD. Investigated causes of extensive, premature failures of parallel 36-inch-diameter AWWA C301 lined cylinder prestressed concrete cylinder pipe and 24-inch-diameter AWWA C200 WSP force mains. Design for the replacement of the 24-inch with 42-inch polyethylene-lined AWWA C151 ductile iron pipe and portions of the 36-inch-diameter with polyethylene-lined ductile-iron pipe totaled in excess of 8,000 feet of force main. Provided construction support services.

Technical Review, City of Santa Monica, Peer Review of Sewer Rehabilitation Program, Santa Monica, CA. Retained to review the contract management aspects of the program to rehabilitate sewers damaged in the Northridge earthquake, the technical basis for rehabilitation systems were made equitable. Assessed multiple techniques, and developed design criteria, which resulted in lower costs and more confidence in the structural capability of the relined sewers.

Project Engineer, City of San Diego, Rose Canyon Trunk Sewer Rehabilitation, San Diego, CA. As part of the design of a parallel 60-inch trunk sewer, two ASTM C700 VCP and ASTM C76 PVC-lined RCP trunk sewers totaling in excess of 20,000 feet were video inspected and externally inspected. Soil corrosivity studies indicated potential for external corrosion that led to special protection engineered into the new sewer design. Rehabilitation techniques evaluated included partial abandonment, joint rehabilitation, and relining. Sections were selectively bypassed or relined as a result of this study.

Project Engineer, Aliso Water Management Agency, Replacement and Reinforcement of 24-Inch ETM Pipeline, CA. Fills more than 40 feet in height for construction of the San Joaquin Hills toll road were determined to severely overstress the pipeline. Consequently, 622 lineal feet of existing 1400-D reinforced concrete pipe (RCP) was replaced with 5900-D RCP, and reinforced concrete encasement was engineered to maximize utilization of other portions of the ETM pipeline. Provided construction support services.

Design Manager, City of San Diego, Morena Boulevard Trunk Sewer Siphon Failure and Rehabilitation, San Diego, CA. The siphon, consisting of twin 42-inch-diameter sewers and a central 39-inch-diameter VCP sewer, had failed. Analysis determined cause was in shear due to differential settlement at the inlet and outlet structures. Developed siphon rehabilitation design for HDPE pipe to accommodate additional future differential settlement.

Project Engineer, City of Tempe, 48th Street Storm Drain, Tempe, AZ. Participated in independent analysis of manufacturer's design of 102-inch-diameter storm drain. D-load as submitted for checking was structurally deficient. The manufacturer took exception and the resulting three edge-bearing tests demonstrated that the pipe had less than half of the required strength. This resulted in a significant change in Ameron's design practices and manufacture of new pipe for the city.

On-Call Contracts

Project Manager and Design Lead, San Diego County Water Authority, On-Call Services Contract

Pipeline 3 Engineering Opinion, San Diego, CA. Provided an independent engineering opinion whether Pipeline 3 could be utilized at higher pressures than originally designed to convey desalinated water from the proposed Poseidon the pipeline design capacity to the Twin Oaks diversion structure.

San Vincente Tunnel Engineering Opinion, San Diego, CA. Provided an independent engineering opinion whether in-place cement mortar lining applied to the 7-mile-long San Vicente tunnel was in conformance with the contract documents and whether it was suitable for purpose.

ANDREW ROMER, PE - CONTINUED

PCCP Wire Breaks Detection - Pipeline 5, San Diego, CA. Performed an analysis of wire breaks detected on PCCP on Pipeline 5 P4 Spec 223 at Nob Hill. The Authority decided to repair both during March 2007.

P3 Mission Trails PCCP Failure Repair, San Diego, CA. Performed a design review for the Authority's emergency connection design between Pipelines 3 and 4 at Lake Murray.

Ultrasonic Testing Engineering Opinion, San Diego, CA. Provided an independent engineering opinion whether ultrasonic testing (UT) should be considered in addition to liquid penetrant (LP) weld testing specified for the San Vicente tunnel project and also evaluated the effectiveness of UT inspection on thin butt-welded joints.

P4 Spec 565 PCCP Relining Project, Paint Mountain to Del Dios Highway, San Diego, CA. Provided an analysis of the effect of very low-strength cellular grout on the structural liner and recommended steps to be taken to increase confidence in the continued serviceability of the liner.

Pipeline 5 Spec 331 Structural Capacity Analysis, San Diego, CA. Analyzed the structural capacity of Pipeline 5 Spec 331, based upon wire breaks detected in the PCCP pipeline. Made recommendations regarding action to be taken to increase confidence in pipe longevity.

Project Engineer, Multiple Projects, Los Angeles Department of Water and Power, On-Call Services Los Angeles, CA. Provided pipeline engineering services for the evaluation of a protective coating system for weld pass holes; the evaluation of extruded polyethylene versus cold-applied polyethylene tape undercoating system; and the evaluation of coating materials as compared to a coal tar enamel coating. Provided forensic pipeline engineering services for the Roscoe Trunkline HDPE pipe failure investigation.

Value Engineering Studies

VE Team Engineer, Metropolitan Water District of Southern California, Value Engineering, Los Angeles, CA. Secondary Inlet to the Domenigoni Reservoir, California. Participated in a value engineering study.

VE Team Engineer, US Army Corps of Engineers, St. Paul District, Devil's Lake Outlet, ND. Participated in a value engineering study.

VE Team Engineer, Calpine, Unocal, and LACOSAN, Southeast Geysers Pipeline, CA. Participated in a value engineering study.

VE Team Engineer, Central Utah Water Conservancy District, Uinta Basin Replacement, UT. Participated in a value engineering study.

VE Team Engineer, San Diego County Water Authority, San Vicente Pipeline/Tunnel, CA. Participated in a value engineering study.

Awards and Honors

American Society of Civil Engineers (ASCE) Pipeline Division– *Stephen D. Bechtel Pipeline Engineering Award*, August 2012

American WaterWorks Association (AWWA) Distribution and Plant Operations Division– *Peak Performance Award*, October 2014

Publications and Presentations

Books

"Answers to Challenging Infrastructure Management Questions," Water Works Research Foundation, 2014, Denver, Colorado ISBN 1978-1-60573-204-6; Dan Ellison, Graham Bell, Stephen Reiber, David Spencer, Andrew Romer, John C. Matthews, Ray Sterling, and Samuel T Ariaratnam.

AWWA Manual M27 Third Edition, "External Corrosion Control for Infrastructure Sustainability" (Chairman and Editor) Published by AWWA, 2013, softcover, 110 pp., ISBN: 978-1-58321-966-9, (Chair of the committee that developed the Manual)

ANDREW ROMER, PE - CONTINUED

"Failure of Prestressed Concrete Cylinder Pipe," Awwa Research Foundation, 2008, Denver, Colorado. ISBN 978-1-60573-013-4 (with Dan Ellison, Graham E. C. Bell, and Brien Clark).

"Corrosion Control for Buried Water Mains - Pocket Field Guide," American Water Works Association, 2009, ISBN 1-58321-725-8 (with Bayard Bosserman II).

"No-Dig and Low-Dig Service Connections After Pipeline Rehabilitation," American Water Works Association Research Foundation, 2007, Denver, Colorado. ISBN 1-58321-xx-x, (with Dan Ellison, Ray Sterling, David Hall, and Michael Graheck).

"External Corrosion and Corrosion Control of Buried Water Mains," American Water Works Association Research Foundation, 2004, Denver, Colorado. ISBN 1-58321-347-3 (with Graham E. C. Bell, Steve Duranceau, and Scot Foreman). The AwwaRF report number is 90987.

"Distribution Infrastructure Management: Answers to Common Questions," American Water Works Association Research Foundation, 2001, Denver, Colorado ISBN 1-58321-118-7 (with Dan Ellison, Graham Bell, Alan O'Brien).

Peer-Reviewed Professional Papers

"Simplified Design Guidelines for Sizing Air Release Valves" (Conference paper #12) presented at ASCE Pipelines Conference, Phoenix, AZ, August 8, 2017.

"Design of Mid-Path Intercept HDD Crossing of the Santa Maria River", (Conference paper #13) Jon Hanlon, Andrew E. Romer, et. al., presented at ASCE Pipelines Conference, Phoenix, AZ, August 8, 2017.

""Design and Construction Case History – South Catamount Transfer Pipeline Float-Sink" Bob Bass, Holly Link, Andrew Romer, and Theresa Wiedemann. Presented at the ASCE Pipelines Conference, August 23-26, 2015, Baltimore, MD.

Pressure Pipeline Design for Water and Wastewater Workshop" Moderator. Based upon draft ASCE Manual of the same name. Presented at ASCE Pipelines Conference, August 23, 2015, Baltimore, MD.

"Optimizing Small Water Main Renewal Using Non-Destructive Examinations", Dan Ellison, Jonathan Leung, Sam Ariaratnam, Andy Romer, and Roy Brander, presented at the ASCE Pipelines Conference, Portland, OR August 4, 2014.

"Design of Supplementary Intake from Lake Sakakawea for the Southwest Pipeline Project" Jim Lennington and Andrew E. Romer, ASCE Pipelines Conference, Portland, OR August 4, 2014.

"Using In-Pipe Condition Assessment to Optimize Small Water Main Renewal" (Dan Ellison, Jonathan Leung, Sam Ariaratnam, Andy Romer, and Roy Brander).presented at NASTT's 2014 No-Dig Show, Orlando, FL Paper MA-T1-02

The Assess-and-Fix Approach to Water Main Rehabilitation" Dan Ellison, Samuel Ariaratnam, Andy Romer & Graham Bell, Presented at the NASTT 2013 No-Dig Conference, Sacramento, CA, March 4, 2013

"Evaluation of 72-in Steel Pipeline for Reverse Flow" Mike Conner, Doug Gillingham, and Andrew E. Romer, ASCE Pipelines Conference Ft Worth, TX, June 24, 2013

"Common and Challenging Questions in Water System Infrastructure Management" Dan Ellison, Graham Bell, and Andy Romer, ASCE Pipelines Conference Miami, Florida, August 22, 2012.

"Who Says You Need Multiple Wire Breaks for a PCCP Pipe to Fail?" John J. Galleher, Jr., and Andrew E. Romer, ASCE Pipelines Conference Miami, Florida, August 20, 2012.

"Integrity Testing of Critical Water Mains, Case Studies Involving Remote Field NDE and Controlled Destructive Examination" R. Dan Ellison, David Lippman, and Andrew Romer, 2011 AWWA Annual Conference & Exposition, Washington, DC, June 14, 2011.

"Failure of Cement Mortar Lining in 144-inch Diameter Pipeline" Mike McReynolds, Tao Peng, and Andrew Romer, presented at ASCE Pipelines Conference, August 30, 2010, Keystone, Colorado.

ANDREW ROMER, PE - CONTINUED

"Alternatives for Condition Assessment of Small Diameter Force Mains" David Lippman, Dan Ellison, and Andrew Romer, presented at ASCE Pipelines Conference, August 30, 2010, Keystone, Colorado.

"Line Stopping for Line Valve Installations on 55-Year-Old Aqueduct," presented at ASCE Pipelines Conference, August 2009 at San Diego, California (with Brett Gray).

"Several Failures of a 16-inch PVC Transmission Main within 12 Years," presented at AWWA Annual Conference, June 2009 and at ASCE Pipelines Conference, August 2009 at San Diego, California (with Robert E. Beamer, Donald R. Kendall).

"Nacimiento Water Project – Design and Hydraulics," presented at ASCE Pipelines Conference, August 2009 at San Diego, CA (with John R. Hollenbeck, Paul R. Kneitz, Steve Foellmi).

"Welding Considerations for Stainless Steel Pipe" presented at 2008 ASCE Pipelines Conference, July 23, 2008 at Atlanta, GA.

"Pipeline Risk Management for Utility System Managers, City Managers, Engineers et al." workshop presented by the ASCE Pipeline Risk Management Committee as part of 2008 ASCE Pipelines Conference, July 22, 2008 at Atlanta, GA.

"Risk Management of Pipeline Corrosion in the Water and Wastewater Industries," presented at the 2007 ASCE Pipeline Conference, August 2007, Boston, Massachusetts (with Paul J. Passaro).

"Failure of Prestressed Concrete Cylinder Pipe," presented at the 2007 ASCE Pipeline Conference, August 2007, Boston, Massachusetts (Graham E. C. Bell, and R. Dan Ellison).

Risk Perception of External Corrosion on Buried Water Mains," panel discussion at 2006 ASCE Pipeline Conference, August 2006, Chicago, Illinois.

"Direct Comparison of Two Electromagnetic Techniques to Determine the Physical Condition of PCCP" presented at the ASCE Pipelines 2005 Conference, August 2005, at Houston, Texas (with John J. Galleher, Jr.; Graham E. C. Bell, PhD).

"Making 'Baggies' Work for Ductile Iron Pipe," presented at the ASCE Pipelines 2004 Conference, August 2004, at San Diego, California (with Graham Bell).

"Fiberglass Pipe Design for Water Mains," presented at the ASCE Pipelines 2004 Conference, August 2004, at San Diego, California (with Glen Hille).

"Rubber Gasket Concrete Pipe Joints…Eliminating the Smoke and Mirrors," presented at the ASCE Pipelines 2004 Conference, August 2004, at San Diego, California (with Kenneth Keinow).

"Solutions to External Corrosion of Buried Water Mains," presented at the ASCE Pipelines 2001 Conference, July 17, 2001, at San Diego, California (Graham Bell).

"69-Inch PCCP Aqueduct Relocation," presented at the ASCE Pipelines 2001 Conference, July 17, 2001, at San Diego, California.

"Causes of External Corrosion on Buried Water Mains," presented at the ASCE Pipelines 2001 Conference, July 16, 2001, at San Diego, California (with Graham Bell).

"Causes of and Solutions to External Corrosion on Buried Water Mains – An AwwaRF Study Update," presented at the American Water Works Association Annual Conference, June 20, 2001, at Washington, DC (with Graham E. C. Bell, PhD, PE).

"Identify Causes and Solutions to External Corrosion on Buried Water Mains – An AwwaRF Study Interim Report," presented at the American Water Works Association Annual Conference, June 14, 2000, at Denver, Colorado (with Graham E. C. Bell, PhD, PE).

"Rethinking the Approach to Engineering Pipelines," presented at the ASCE Pipelines in the Constructed Environment Specialty Conference, August 25, 1998, at San Diego, California.

"Avoiding Common Thrust Restraint Mistakes," presented at the ASCE Pipelines in the Constructed Environment Specialty Conference, August 24, 1998, at San Diego, California.

ANDREW ROMER, PE - CONTINUED

"PVC-Lined Steel Pipe Bridges for Gravity Sewers," presented at the ASCE Pipeline Crossings 1996 Specialty Conference on June 19, 1996, at Burlington, Vermont.

"Tunneling Bid Alternative for 72-Inch (1800mm) Diameter Sewer Project," presented at the North American Tunneling Conference, June 6, 1994, at Denver, Colorado.

"Recent Advances in the Application of Cold-Applied Tape Coatings for Large Diameter Water Pipelines," Presented at the National Association of Corrosion Engineers' Western Regional Corrosion Conference, November 4, 1993, at Berkeley, California.

"Study, Design, and Replacement of Failed Large Diameter Force Mains," presented at AWPCA California/WEF/National Specialty Conference "Collection Systems - Operation and Maintenance," June 27-30, 1993, at Tucson, Arizona (with Ben Movahed).

"E' and its Variation with Depth," Discussion: ASCE Journal of Transportation Engineering, July 1989, P459.

4 PROPOSAL COSTS

Costs for AECOM services on this project have been submitted in a separate file from the rest of this proposal, as requested in the RFP.

APPENDIX A:
VENDOR OUTREACH QUESTIONNAIRE

CITY OF SAINT PAUL
Vendor Outreach Program Ordinance Questionnaire
Business Inclusion Data – Mandatory Submission *

Company/Firm Name: AECOM

Street Address: 800 LaSalle Avenue, Suite 500, Mnpls., MN 55402

Contact Person: John Lapointe

E-Mail: john.lapointe@aecom.com Phone Number: 612-376-2587

Project Name: Prestressed Concrete Cylinder Pipe (PCCP) Condition Assessment

Supplier Portal (stpaulbids) Event #: 708

Failure to complete and include this questionnaire with the bid/quote/request for information/request for proposal/request for qualifications, or any other type of solicitation not listed herein, will deem it non-responsive and it will be rejected.

☑ *(check if applicable)* At this time there are no subcontracting opportunities as we are self-performing all work. If the scope of our work changes and we will not be self-performing this work, we will (1) consult the CERT list to look for a qualified subcontractor to perform the work and (2) notify compliance of the change.

Anticipated percent of available business opportunity for this project that will be awarded to CERT certified businesses:

MBE _____% SBE _____ % WBE _____%

Percentages and estimated dollar amounts are required. Attach additional pages if necessary.

Name of Certified Vendor	MBE, SBE, or WBE	Type of Work or Supplies	Estimated Subcontract Dollar Amount

* I understand that, pursuant to Chapter 84 of the City of St. Paul Code of Ordinances, the Vendor Outreach Program applies to this bid, and under the Vendor Outreach Program, the City requires submission of the Vendor Outreach Program Questionnaire in order for the bid to be responsive. I further understand that I will have up until the time of award, or 10 days after bid opening, whichever occurs first, to complete and submit my Vendor Outreach Program Questionnaire. Failure to submit this form will result in my bid being treated as nonresponsive.

APPENDIX B:
PAPERS FROM ASCE 2018 PIPELINES CONFERENCE

Condition Assessment and Asset Preservation Rationalization for the St. Paul Regional Water Services (SPRWS) in St. Paul, MN

Chris Macey, P.Eng., M.ASCE[1]; Marshall Gibbons[2]; Tom Degen, P.E.[3]; Rich Hibbard, P.E.[4]; and David Wagner, P.E.[5]

[1]AECOM Canada Ltd., 99 Commerce Dr., Winnipeg, MB. E-mail: chris.macey@aecom.com
[2]AECOM Canada Ltd., 99 Commerce Dr., Winnipeg, MB. E-mail: marshall.gibbons@aecom.com
[3]AECOM, 200 Indiana Ave., Stevens Point, WI. E-mail: tom.degen@aecom.com
[4]St. Paul Regional Water Services (SPRWS), 1900 Rice St., Saint Paul, MN. E-mail: richard.hibbard@ci.stpaul.mn.us
[5]St. Paul Regional Water Services (SPRWS), 1900 Rice St., Saint Paul, MN. E-mail: dave.wagner@ci.stpaul.mn.us

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ABSTRACT

St. Paul Regional Water Services (SPRWS) supplies drinking water to nearly 415,000 customers in the city of St. Paul and neighboring communities. The primary source for this water is the Mississippi River at Fridley, where an intake pumping station with a capacity of 340 MLD (90 MGD) pumps water into the raw water system. The raw water system is comprised of 41 km (25.5 miles) of various pipe types and vintages including cast-in-place concrete (1924 and 1936), riveted steel (1924), welded steel (1958, 1960), reinforced concrete pipe (1958), and prestressed concrete pressure pipe (1989/1990). The diameters range from 1500 mm to 2250 mm (60" to 90"). The current day replacement value of the raw water conduit system is $1.2 billion. Given that 88% of the concrete pipe was over 90 years old and 99% of the steel was approaching 60 years and older, the condition of the pipes needed to be understood with greater certainty. In 2016/2017, SPRWS initiated a large scale condition assessment program to determine the condition of all 41 km (25.5 miles) of pipe. Using a vast array of condition assessment techniques over 98% of the system was inspected and assessed. Using risk-based programing techniques a very innovative $24 million rehabilitation program was developed; phased in over a 15 year period to extend the projected service life of the raw water system for another 100 years or more.

INTRODUCTION

St. Paul Regional Water Services (SPRWS) supplies an average of 170 MLD (45 million gallons per day) of drinking water to nearly 415,000 customers in the City of St. Paul and neighboring communities (see Figure 1) via the McCarrons Water Treatment Plant (WTP). The WTP is supplied raw water via 41 km (25.5 miles) of low head pressure conduits, the construction of which dates back as early as 1924. Aside from visual observations of the interior of the conduits during routine maintenance and early repair programs, no rigorous physical condition assessment of the conduits had ever been completed. Portions of the conduits had not been inspected prior to this program in more than 25 years.

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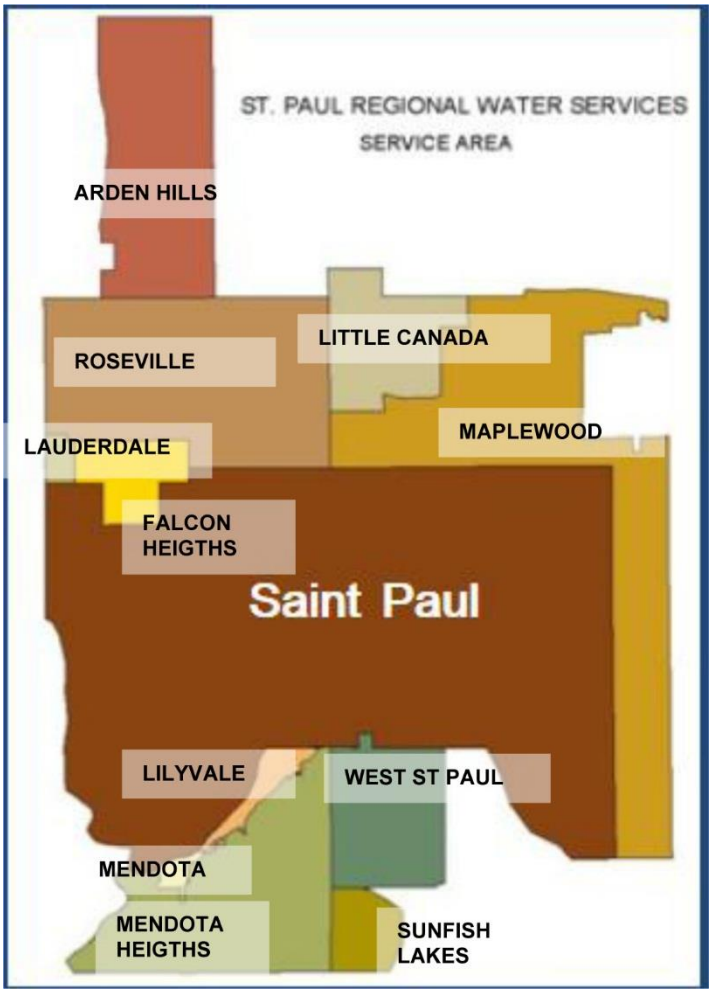

Figure 1: SPRWS Service Area

EXISTING RAW WATER SYSTEM AND BACKGROUND

SPRWS's raw water is conveyed from various surface and groundwater sources to the McCarrons WTP via its raw water supply system (Figure 2). The 41 km (25.5 miles) of raw water conduits that make up the bulk of the system operate as twin pipelines over three distinct regions, as follows:

- The Mississippi Conduits, which convey water eastward from the Mississippi River at Fridley to Charlie Lake in North Oaks, a distance of 12.8 km (8 miles).
  - Conduit #1 (M1) – original 1500 mm (60-inch) riveted steel and cast-in-place reinforced-concrete (CIPC) conduit, constructed in 1924.
  - Conduit #2 (M2) – 900 mm and 1500 mm (36 and 60-inch) welded steel conduit, completed in 1960.
- The Pleasant Conduits, which transfer water southward from Pleasant Lake in North Oaks to Sucker Creek / Vadnais Lake in Vadnais Heights, a distance of 0.8 km (0.5 miles).
  - Conduit #1 (P1) – original 1500 mm (60-inch) CIPC conduit, constructed about 1936.
  - Conduit #2 (P2) –1500 mm (60-inch) precast reinforced-concrete pipe (RCP) conduit, completed 1958.

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- The Vadnais Conduits, which transfer water southward from Vadnais Lake and groundwater wells along the conduit route to the Water Treatment Plant on Rice Street in St. Paul, a distance of 7 km (4.4 miles).
  - Conduit #1 (V1) – original 2250 mm (90-inch) CIPC conduit, constructed in 1925.
  - Conduit #2 (V2) – 2250 mm (90-inch) welded steel conduit, constructed in 1958.

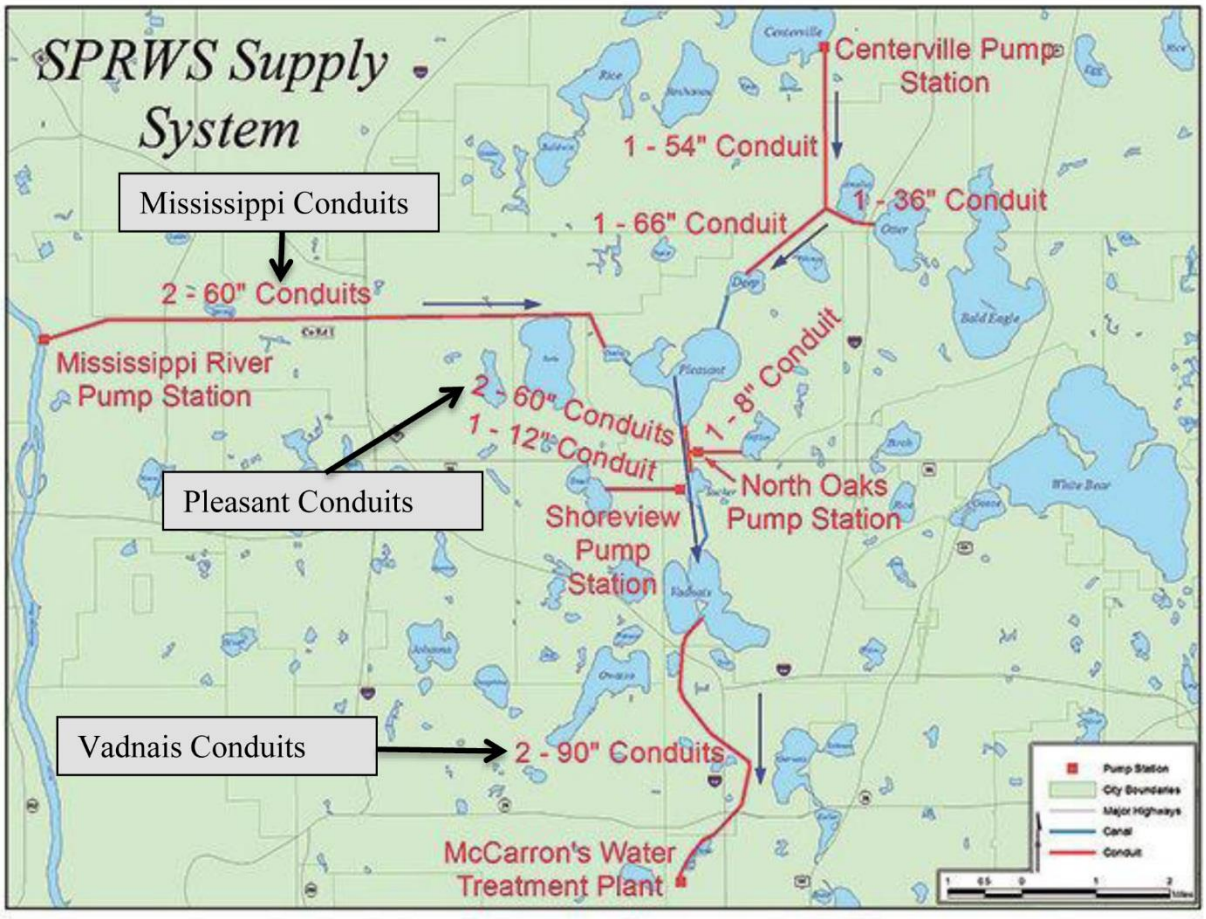

Figure 2: St. Paul Regional Water Services' Raw Water Supply System.

The conduits operate under low head service with an initially elevated hydraulic grade line (HGL) to get over a high point in the ground profile at the west end of the Mississippi conduits, and then transitioning to open channel flow or very low head service over the remainder of the distance (see Figure 3). The Mississippi and Vadnais Conduits are situated in dedicated corridors with facilitated access for inspection and repair. The Pleasant Conduits are situated in a golf course.

PRIOR ASSESSMENT AND MAINTENANCE HISTORY

In the past, SPRWS staff has performed maintenance on the concrete conduits, most extensively the M1 Conduit, to repair joint leaks (using internal joint seals) and restore deteriorated pipe walls. Reported maintenance on the steel conduits included installation of reinforced-concrete liners, sealing of cracks in mortar linings using cementitious slurries and leak repairs where full wall pinhole corrosion had occurred. Additionally, some portions of the

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conduits have been replaced due to settlement, external corrosion, or roadway development.

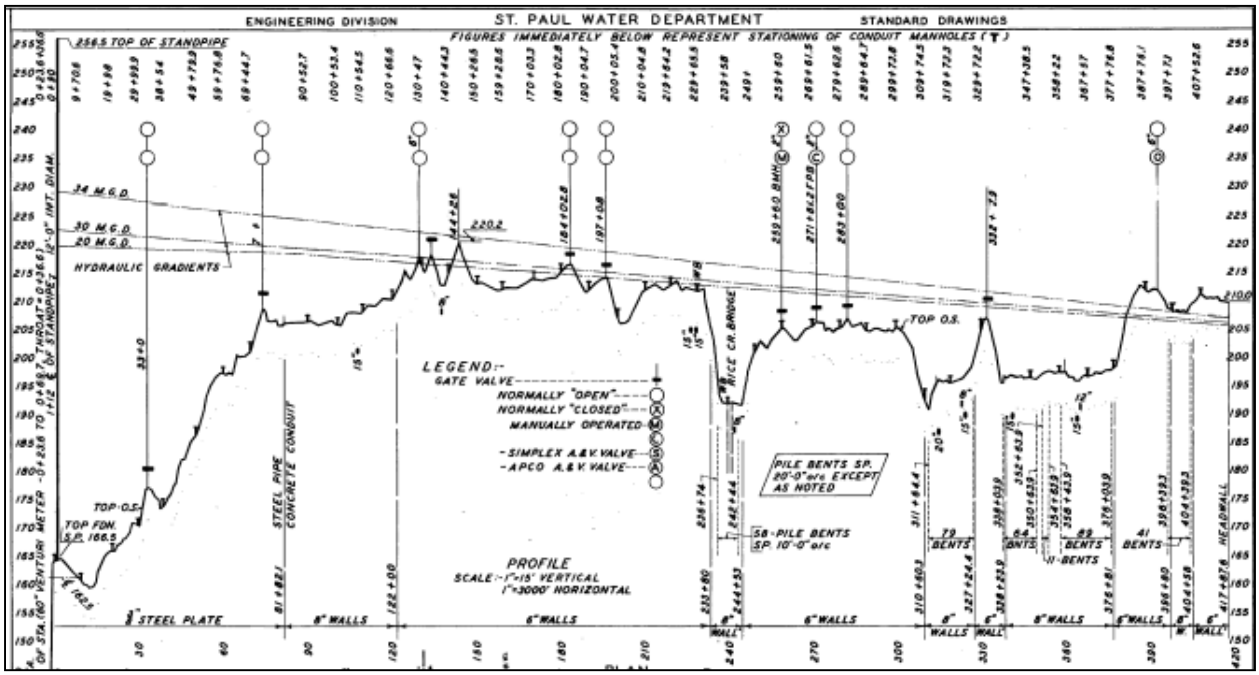

Figure 3: Illustrative Hydraulic Grade Lines from Mississippi River to Charles Lake (Drawing A2 3599)

The most comprehensive assessment undertaken prior to the present investigations was a corrosion survey carried out on the Vadnais and Mississippi steel conduits in June 1971 by the Harco Corporation (Harco – 1971). The 1971 assessments were carried out using relatively standard External Corrosion Direct Assessment (ECDA) techniques (close-interval pipe-to-soil potential surveys, etc.). Harco had concluded that considerable pitting corrosion was evident on the steel lines and they recommended implementation of active external corrosion protection systems. None of Harco's recommendations, however, were adopted. Harco also pointed out a key practical aspect of the pipe deterioration associated with the raw water lines, which logically explained the lack of implementation at the time. The pressure head over much of the raw water lines is so low that active leaks are not always readily apparent and don't surface in some cases. Functioning as largely gravity lines in many areas, the perceived need for corrosion protection was not as evident, even though Harco had confirmed the presence of considerable active pitting corrosion processes on the steel lines. For much of the concrete lines, with known joint deficiencies and some cracking that also compromised hydrostatic integrity, a similar thought process may have existed; not all leaks along the conduits surface in the manner that leaks on conventional watermains under higher pressure head readily surface.

Given the above and that 88% of the concrete pipe was over 90 years old and 99% of the steel was approaching 60 years and older (see Figure 4 and Figure 5), the condition of the pipes needed to be understood with greater certainty.

CONDITON ASSESSMENT APPROACH

The Condition Assessment approach for all concrete pipe was patterned after ACI 201.1R-08 (ACI 2008) for assessing Concrete Structures in Service while the general technical approach

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outlined in NACE Standard Practice SP0210 (NACE 2010) was used as a basis for assessment of all steel pipe. All internal inspections catalogued defects using NASSCO PACP defect categorization protocol to facilitate the use of a NASSCO standard database structure to manage spatial referencing for all structural and service related observations.

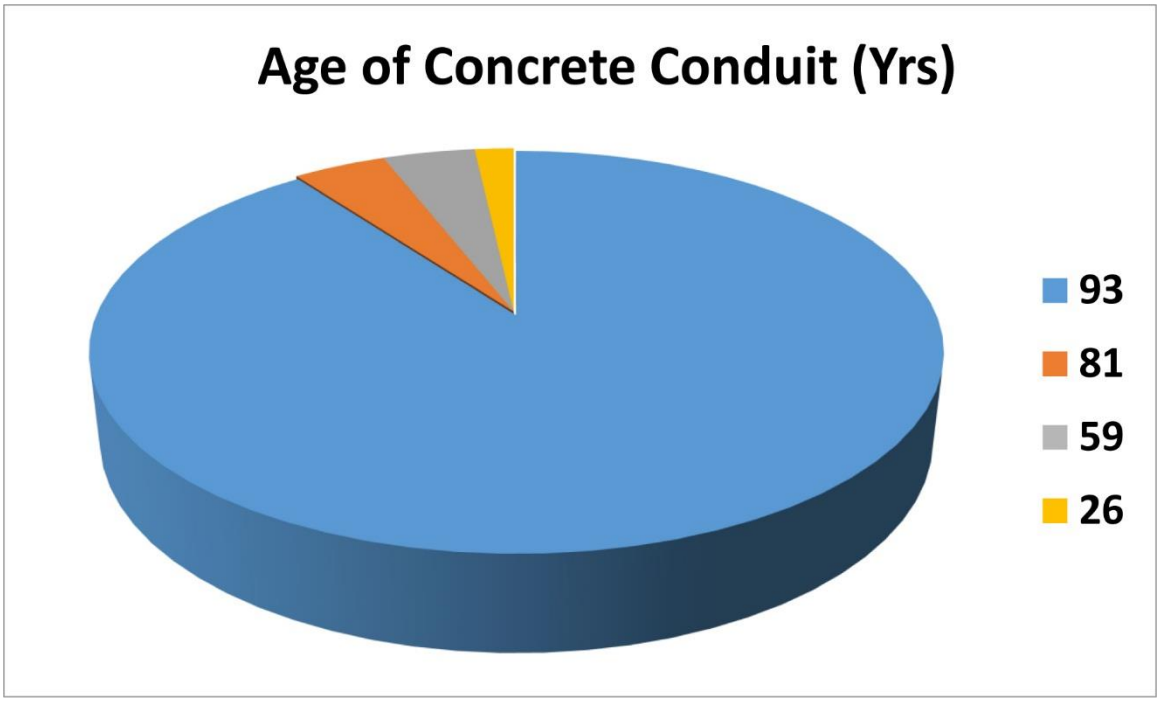

Figure 4: Age of Concrete Conduits

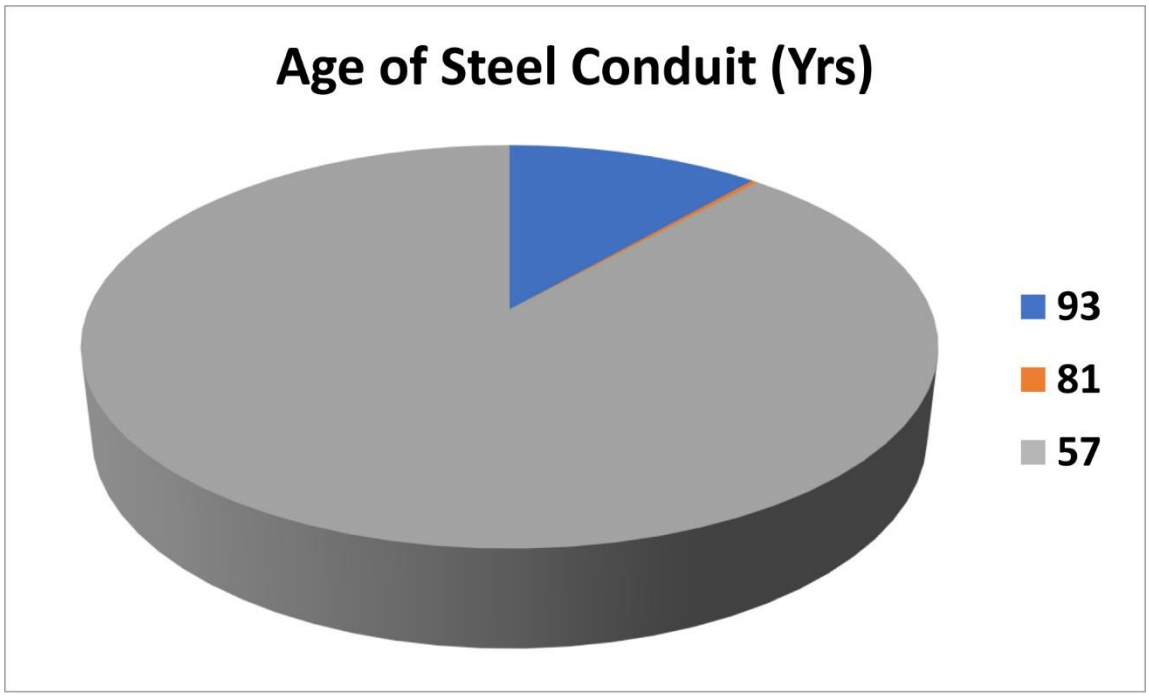

Figure 5: Age of Steel Conduits

The overall program included the following components and approach to acquire condition

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assessment data, to post-process it, and to facilitate its interpretation:

1. GIS screening of the conduits to identify locations at elevated risk of deterioration or failure based on the following parameters:
    - Pipe material and original construction features.
    - Regional soil and groundwater data from the Web Soil Survey database maintained by the USDA and previous studies in the area. Screening considered that:
        - Locations having lower resistivity values would increase corrosion risk for ferrous metals or could exacerbate reinforcing steel degradation in severely cracked concrete pipe.
        - Locations having elevated sulfate ion contents that could lead to premature concrete degradation or concentration cell corrosion of the steel conduits, and
        - Locations in close proximity to higher traffic volumes areas would be more likely to have elevated chloride ion contents from de-icing salts (and correspondingly higher potential for increased corrosion activity)
    - Previous maintenance history
    - Land use that could cause environmental concerns
2. A three-stage inspection program to observe conduit condition and acquire data needed to facilitate office assessment studies:
    - Stage 1 –Internal walk-through video inspection by two Inspectors, with the first inspector locating pipe defects and marking pipe joint numbers on the pipe wall for location reference, and the second inspector capturing a video record of the conduit using a hand-held video camera.
    - Stage 2 – Detailed visual, sounding and, where appropriate, ultrasonic thickness inspection inspection of the interior of the conduits by two Inspectors, focusing on significant defects detected during the video inspection and a limited but focused inspection of selected internal joint seals (WEKO seals) by a specialist Contractor.
    - Stage 3 – Visual inspection, sounding and, where appropriate, ultrasonic thickness inspection of the exterior of the conduits at up to 20 sites, the locations of which were selected based on USDA soil corrosivity data and observations from the internal inspections. Physical sampling included securing of core samples from concrete, mechanical properties and petrographic assessment and soil sampling to ascertain site specific chemistry and electrochemistry characteristics.
3. Based on the data accumulated from the field inspections, office studies were carried out to:
    - Assess the condition of the pipe; confirm the primary deterioration mechanisms that are responsible for the observed condition, assess structural condition to assess current and future failure risk.
    - Ascertain where it would be prudent to acquire additional information to increase the knowledge of condition, deterioration processes and remedial requirements.
    - Assess residual life in areas where deterioration had occurred or active deterioration processes were present.
    - Develop a prioritized, comprehensive maintenance and rehabilitation program to extend the life of the raw water supply asset for a minimum of 50 years.

The total cost of the condition assessment program (inclusive of all third party testing) was approximately $455,000 or about $11/m ($3.40/foot).

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SYNOPSIS OF EXISTING CONDITION

Based on the review of all defects, their nature, the exposure environment, the applied loads on the pipe and the observed deterioration processes present, the following assessment was made with respect to the condition of each primary pipe material:

1. Riveted steel pipe (RSP) and Welded steel pipe (WS)
    a. Each era of steel pipe was predominately constructed with a coal tar epoxy style of coating (wrap and/or enamel) or a flexible coating, cement mortar lining, recognized ASTM grades of steel and jointed in a manner that has largely created an electrically continuous pipe.
    b. The external environment around the pipe varies from mildly to moderately corrosive to ferrous metals, with a slight trend in areas closer to busier roadways of increasing corrosivity over time, likely due to the surficial use of de-icing salts on roadways. As such, the increasing corrosivity over time will likely continue in areas where the use of de-icing salts is prevalent.
    c. The natural corrosivity of the external environment along the Vadnais Conduit is markedly more aggressive than that along the Mississippi Conduits (this was clearly evident in Harco's 1971 survey and remained evident in the test excavations carried out for these studies).
    d. While the coatings have been very effective at preserving the structural integrity of underlying steel, there are active exterior corrosion processes along the entire length of the steel conduits. Close interval pipe to soil potential (CIPS) surveys conducted as far back as 1971 confirmed this as well as internal and external visual and UST testing carried out in these investigations. While the rate of external corrosion is highly variable along the length of the pipeline, exterior face corrosion has initiated numerous pinhole failures over the years. If external face corrosion is left unaddressed, the steel pipe will experience increased failure rates and have a finite life as long term increases in the spatial coverage of pitting corrosion can eventually lead to structural failures.
    e. The cement mortar lining in many areas has experienced cracking, both circumferentially and longitudinally. It is associated with deflection in excess of the allowable deflection for the lining or longitudinal bending of the pipe. While the lining damage is minor and in most areas has not compromised the corrosion protection offered by the lining, it needs to be repaired to prevent internal corrosion over time which would lead to widespread lining loss.
    f. The original structural design of all steel conduits relative to their applied loads was determined to be very robust. Two localized areas were observed (the Rice Creek Siphon, MH47-MH48 and south of County Road I, MH77-MH78) where localized buckling had occurred. Based on the assessment in both cases the likely root cause was the original construction method; as opposed to buckling associated with any active deterioration process.
    g. With the exception of the two locally bucked areas, the structural stability of the steel pipe from all eras is excellent. While deflection is present in many areas at levels well in excess of the service cracking limit for the liners, the overall pipe-soil interaction is excellent with no evidence of progressive loss of pipe-soil structure whatsoever. This is indicative of a host pipe that still has considerable inherent ring stiffness.

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h. While the two locally buckled areas need to be repaired, they have likely existed in that state for some time period and are not at risk of imminent collapse.

Figure 6: Typical View of Riveted Steel Pipe (RSP).

While the steel pipe has a considerable number of defects present and active deterioration processes present, they are largely service related as opposed to structurally related at this time. If the deterioration processes can be mitigated or arrested and the structural defects repaired, the host pipe would be anticipated to have a very long residual life. The length of the residual design life will largely be dependent on the techniques employed to arrest future deterioration but realistically can be extended to last many hundreds of years, as all active deterioration processes are readily mitigated. Representative shots of the internal and external condition of steel pipe are presented in Figure 6 and Figure 7.

2. Cast-in-place Concrete (CIPC) Pipe
   a. Both vintages of CIPC (1924 Mississippi #1 and Vadnais #1, and 1936 Pleasant #1) are conservatively designed pipe structures by present day standards and their current applied loads.
   b. Given the current maximum cover experienced by the pipes and their diameter, none of the pipe walls will have their reinforcing schemes governed by radial tension, which means that all reinforcing schema are applicable to the current loading situations. Significant increases in cover, however, could introduce this type of failure mode, so surface development over the pipes needs to be undertaken with considerable caution.

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c. The native soils, based on the regional geology review have negligible levels of sulphate ions present in both soil and groundwater. The soils do not have measureable levels of naturally occurring chlorides but do at some locations show evidence of environmentally induced chlorides at pipe depth, likely due to surficial road de-icing practices. The soils are also neutral to slightly alkaline with respect to hydrogen ion content.
d. Aside from the slightly elevated chloride levels at some locations, the external soil environment along the route is reasonably benign with respect to its potential to prematurely break down concrete. Measured chloride levels were still below threshold concern levels (<500 mg/l) but would be expected to increase over time if current de-icing practices continue. Elevated chlorides over time are likely a localized issue at busier road crossings as opposed to a generalized issue along the entire pipe alignments.
e. Based on 15 cores taken from Mississippi #1 (7) and Vadnais #1 (8) the concrete strength is exceptionally high for concrete of these vintages (all corrected strengths are in excess of 41 MPa - 6000 psi).
f. Petrographic analysis of one core along the Mississippi #1 and one core on Vadnais #1 confirms that the concrete is:
    i. Non-entrained and, therefore, susceptible to freeze-thaw damage
    ii. Vulnerable to break down by sulphates if present
    iii. Moderately resistant to penetration by chlorides
    iv. Made with a high quality aggregate that is not subject to undesirable alkali-aggregate reaction
    v. Cured into a very good quality cement paste mixed with fine and coarse aggregate that would be expected to be very durable if its exposure conditions don't exploit its vulnerabilities as noted above.
g. Visual examination of the cores (Figure 8) illustrates the incidence of a number of original construction flaws, in terms of localized honey-combining associated with imperfect placement practices (e.g. poor concrete consolidation). However, the overall the quality of the original concrete wall construction is generally very good.
h. The inspection program highlighted the following key concrete defect issues:
    i. Joint defects related to the original joint design and by-passing of the copper water stop. Nearly all of the joints on the Mississippi Conduit #1 CIPC have been previously repaired with internal joint seals. Based on the review of the seals, it would appear widespread joints were repaired but not tested to confirm whether they were leaking or not. They appear to have been repaired on the assumption that a pronounced circumferential crack in the joint mortar would by-pass the copper water stop as opposed to confirming failure of the stop through joint proof testing.
    ii. A number of the seals on joints that do leak are not functional (see Figure 9). Based on the review this has occurred due to poor installation practices as opposed to there being anything inherently wrong with the repair method selection. Based on the joint defects observed, internal compression seals would still appear to be a viable repair method, as long as a fundamentally different approach is undertaken for installation and acceptance.

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iii. Pipe segment defects which fell into two categories; service related defects which if left unrepaired would contribute to further deterioration along the pipeline; and structural defects, which if left unrepaired would eventually lead to collapse of the pipe. The vast majority of observed structural defects were service as opposed to structural defects.

vi. All defects noted are repairable by a variety of repair methods.

Figure 7: Vadnais Test Pit 4: 1958 V2 steel pipe in good condition.

While the CIPC has a considerable number of defects present and active deterioration processes present associated with its service level defects it is largely very competent concrete, with a structural design that is well matched to its current loading. Further, the exposure environment is relatively benign to the concrete and it is not actively being broken down by either widespread interior face or exterior face deterioration processes (see Figure 10 for typical exterior condition). If the defects are repaired and the pipe is maintained over time, it would be anticipated to have a very long residual design life (e.g. greater than 100 years).

REHABILITATION PROGRAM

Based on the nature of the defects present and the large amount of existing pipe in excellent condition the adoption of renovation as opposed to replacement rehabilitation techniques was deemed to be most cost effective approach. This was rationalized using conventional life cycle costing techniques.

While there are numerous defects in the raw water piping (over 14,000), the defects are

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largely clustered in widely spatially varied locations. The average spatial extent of defects in each conduit varies from as low as about 2% in Pleasant Conduit #1 to 14% in Mississippi #1. This overwhelmingly suggests that a find-and-fix strategy would be more appropriate than the use of continuous relining technologies.

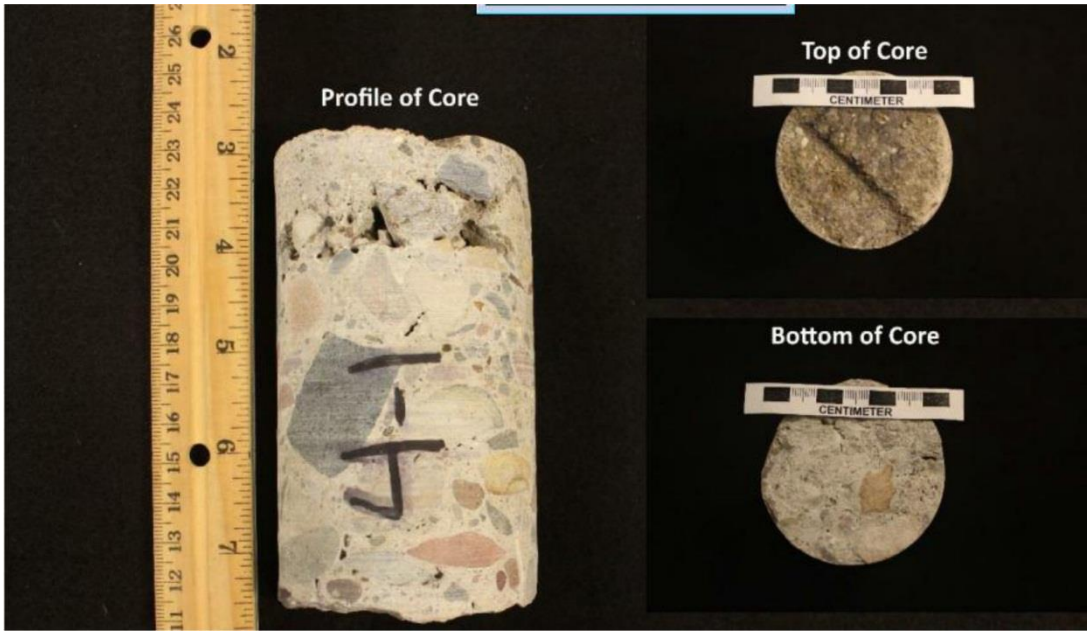

Figure 8: Profile of Core 4-1 on Mississippi Conduit #1

Figure 9: Joint MH.28A-J29: WEKO Seal with "Sprung" Retaining Band.

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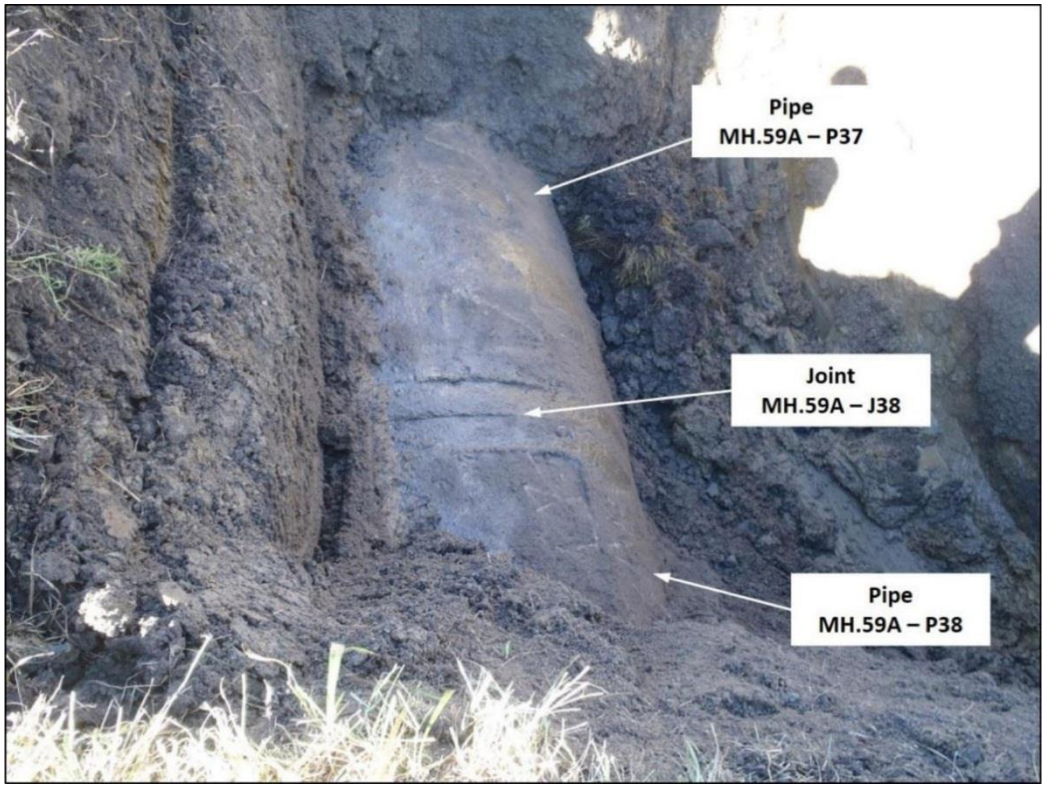

Figure 10: M1 Test Pit 6 on Pipes MH.59A – P37 and P38.

The following programs were recommended for each primary pipe material:

1. Concrete Pipe
   Based on the existing defects present in concrete pipe service and structural repair programs were recommended using the following repair techniques:
   a. Internal Joint Seal Repairs
   b. Crack Injection (polyurethane injection)
   c. Polymer Concrete – service related repairs
   d. Structural Repairs – polymer and site specific mix repairs and localized strengthening
2. Steel Pipe
   Steel pipe repairs and mitigation works to be undertaken included:
   a. Two structural repairs of localized buckled pipe.
   b. Addressing external face corrosion in a two-step process:
      i. Carry-out an External Corrosion Direct Assessment (ECDA) Survey program as per NACE Recommended Practice RP0502-2002, Pipeline External Corrosion Direct Assessment, to characterize the areas that are actively corroding, to evaluate the exterior coating condition, and to facilitate cathodic protection design.
      ii. Implement a staged cathodic protection (CP) program to arrest external face corrosion.
   c. Addressing internal face corrosion by carrying out “find-and-fix” repairs to the internal mortar lining.

To rationalize timing and overall prioritization of the program, a conventional risk based approach was used. Based on the nature of the deterioration processes present an overall program duration of about 15 years was considered prudent.

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Failure probability was related to the severity of the defects being restored (or anticipated environment in the case of mitigative works). Based on the degree of redundancy present in the pipelines and the fact that most of the pipelines are readily accessible for repair, a relatively simple consequence model was developed which attached a 1 to 3 rating to the location of the sections requiring repair with elevated consequence attached to:

- Interstate and major road crossings, and
- The isolated areas where poor access would increase repair cost

Using this simple 3 by 3 matrix, Risk values were assigned to all designated rehabilitation and mitigative work packages. These varied in severity from a low of 1 (Low-Low designation) to a maximum value of 9 (high-high designation).

The Risk Ratings were then used to prioritize an overall work program based on the general guidelines noted in Table 1 below.

Table 1: Risk versus Capital Programing Implications

Risk Rating	Capital Program Implications
7-9	1-5 year
4-6	6-10 year
1-3	11-15 year

These capital program implications were then applied to the raw work programs and the resultant capital priority matrix presented in Table 2 was developed.

Table 2: Recommended Risk-Based Prioritization Strategy

Overall Risk - Phasing	***Risk Score***	*Internal Joint Work*	*Crack Injection*	*Polymer Concrete*	*Structural Repairs*	*Mitigative Works*	***Total Program***	***Timing (years)***
High	7-9	$1,720,000	$730,000	$1,890,000	$1,340,000	$2,880,000	$8,560,000	***1-5***
Medium	4-6	$790,000	$20,000	$940,000	$680,000	$2,880,000	$5,310,000	***6-10***
Low	1-3	$2,150,000	$730,000	$1,950,000	$1,630,000	$2,880,000	$9,340,000	***11-15***
Totals		***$4,660,000***	***$1,480,000***	***$4,780,000***	***$3,650,000***	***$8,640,000***	***$23,210,000***	

CONCLUSIONS

In 2016/2017, SPRWS initiated a large scale condition assessment program to determine the condition of all 41 km (25.5 miles) of pipe, the active deterioration processes present, the residual design life of each component and the most advantageous rehabilitation program to preserve the reliability and extend the life of the asset. The total cost of the condition assessment program was approximately $455,000 or about $11/m ($3.40/foot).

Using a balance of ACI 0201.1 assessment techniques for concrete and NACE, SP0210 external corrosion direct assessment (ECDA) techniques for steel the condition of over 98% of the pipe was directly assessed and a long term rehabilitation program was prepared used risk based prioritization methodology. The rehabilitation program includes structural, service, deterioration mitigation (e.g. external corrosion protection) related repairs and is scheduled for implementation over a 15 year period. The $23.2 million program very innovatively is valued at approximately 2.0% of the asset replacement value to extend the projected service life another 100 years or more.

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North Fork Siphon Condition Evaluation

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ABSTRACT

The North Fork Siphon is an essential element of the Central Utah Project, a vast network of water facilities operated by the Central Utah Water Conservancy District (CUWCD) to deliver clean water to customers in northeastern and central Utah. The 72-inch diameter siphon was completed in 1987, and was constructed using primarily prestressed concrete cylinder pipe (PCCP). The siphon has a lay length of 4,750 feet, a vertical elevation difference of 716 feet, and an inclination in places up to 70%. CUWCD commissioned two visual/sounding and electromagnetic (EM) inspections of the siphon in 2009 and in 2014. Of 233 PCCP segments inspected in 2009, eight pipes were identified as having significant structural damage (wire breaks). In 2014, only one of these 8 pipes was reported as having significant structural damage. This discrepancy in EM results led CUWCD to commission an independent inspection of the siphon in November 2016. The number of defects detected during the new inspection was much greater than anticipated: 196 pipes exhibited serious defects, with 24 having structural defects indicative of incipient failure. This paper provides an overview of the inspection and its findings, the condition assessment and pipe rating system devised for the siphon, and the options presented for managing the siphon.

INTRODUCTION

The North Fork Siphon is an essential element of the Central Utah Project, a vast network of water facilities operated by the Central Utah Water Conservancy District (CUWCD) to deliver water to its customers in northeastern and central Utah. It was designed by the United States Bureau of Reclamation (USBR) and constructed between May 1985 and June 1987 by Harrison Western Corp.

Details of the siphon's construction were available from the construction drawings (USBR, 1983) and a Technical Construction Report (USBR, 1988). The siphon crosses the valley of the North Fork of the Duchesne River, and connects the Stillwater Tunnel on the east side to the Hades Tunnel on the west side. The siphon is 72-inches in diameter and is comprised primarily of embedded-core prestressed concrete cylinder pipe (PCCP); it has 233 PCCP segments and 9 mortar-lined steel pipe segments located at the siphon inlet and outlet, at major grade transitions, and at a blow-off chamber near the river.

The horizontal station length across the valley is approximately 4,375 feet but the actual lay length of the siphon is approximately 4,750 feet. The elevation difference from the east siphon entrance to the low point west of the blow-off chamber is 716 feet, and the maximum slope inclination is approximately 70%. Pipes on the slopes were anchored to bedrock using 112 pipe anchors and three pipe collars, to provide lateral stabilization and relieve vertical loads placed on

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lower pipes as the pipes were stacked, using a system of rock bolts, pipe anchors, and pipe collars.

PREVIOUS INSPECTIONS

CUWCD commissioned two visual/sounding and electromagnetic (EM) inspections of the siphon, the first in 2009 and the second, a recommended follow-up inspection to detect any advancement of deterioration, in 2014. A comparison of the 2009 and 2014 visual/sounding inspections indicated degradation had advanced at some locations; however, the two EM inspections did not correlate well. Of 233 PCCP pipes inspected in 2009, eight were identified as exhibiting EM characteristics indicative of significant structural damage (prestressed wire breaks). In 2014, only one pipe was reported as exhibiting EM characteristics associated with wire breaks, 12 were deemed to have anomalous EM regions, and the remaining 220 exhibited no indication of wire breaks or anomalies. Of the eight pipes identified in 2009 as exhibiting characteristics associated with wire breaks, five were reclassified as having anomalous EM regions and two were reclassified as not exhibiting distress. This discrepancy in EM results, coupled with visual observations made during the 2014 inspection, led CUWCD to commission an independent visual/sounding inspection of the siphon by AECOM. This inspection was undertaken November 16-20, 2016.

INSPECTION APPROACH

The study of PCCP deterioration processes is extensively reported in AWWA Research Foundation Report 4034 (Romer et al, 2008). The most destructive failure scenario for PCCP occurs when applied stresses exceed the design stress of the pipe, leading to the development of cracks in the pipe's relatively-thin external mortar coating. Cracking of the mortar enables water to more easily penetrate to the prestressed wires, where it then facilitates their corrosion. As the wires corrode and weaken and can no longer maintain the pipe core in compression, hoop stress is redistributed to the steel cylinder. The cylinder then expands radially, causing the core and mortar coating to crack in tension. The longitudinal cracks that eventually develop and are visible on the interior of the pipe are the most common visual evidence of wire failure. As deterioration advances the core disbonds from the steel cylinder, creating hollow areas behind the concrete that can be detected by sounding. Water may then be able to reach the cylinder, which may eventually corrode to perforation. As the cylinder fails in tension the core shear strength is exceeded. At this stage the failure pressure for the pipe can actually be lower than the cylinder bursting strength due to site-specific stress factors.

Since the condition of the PCCP was the primary concern, the visual and sounding inspection would focus on those segments, with only general observations being made of the steel pipes. The technical approach for the overall inspection of the PCCP followed the protocol outline by ACI 201.1R-08, with specific attention to capturing defects that highlighted the condition state and active deterioration processes on PCCP.

Pipes were sounded using standard masonry hammers with a smooth, flat square head. The full circumference of the pipe was sounded on the spigot and bell ends at each joint, and along the pipe barrels at 5-foot intervals. As almost no hollow areas were detected solely within visibly undamaged barrels of the pipes, the distance between soundings in barrels was increased, and generally was performed around other notable defects such as mortar spalls and cracks.

Owing to the remote site location, a confined work space, and the steep pipe slopes, careful planning was a critical element to ensuring the safe completion of the inspection. A rigging

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contractor was subcontracted to provide confined space entry support and to erect a motorized working stage inside the siphon that could be pulled up the steep slopes using an electric winch (Figure 1).

Figure 1 – Winch-Driven Working Stage in 72-Inch Siphon (CUWCD).

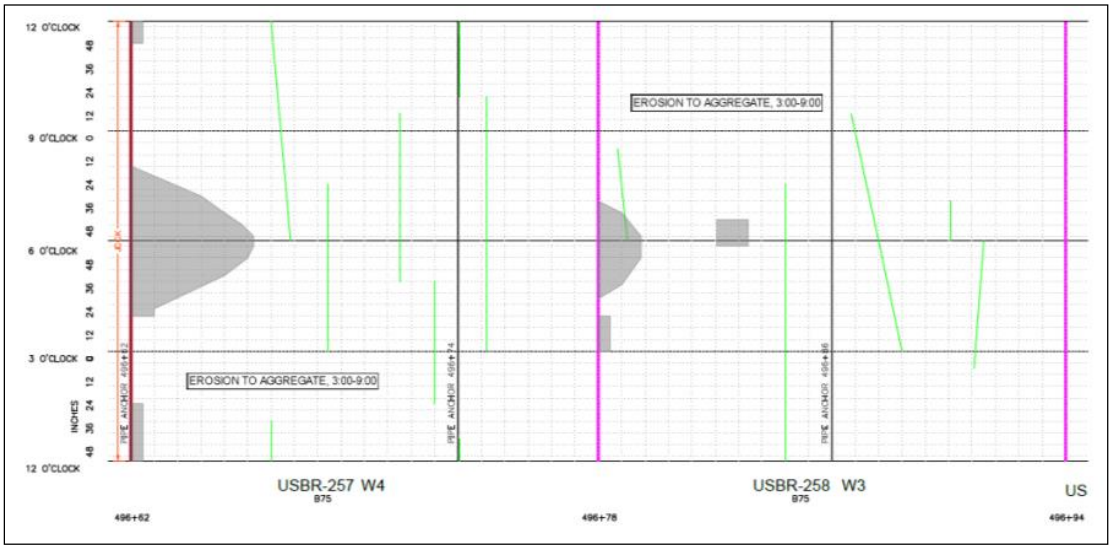

Figure 2 – Example of Pipe Segment Map, Showing Defects.

Inspectors utilized standard PPE, as well as a fall restraint system for fall protection, and were tied off separately from the work stage. Natural ventilation through the access points at each end of the siphon was adequate to provide a safe working atmosphere so additional precautionary actions were not required. Communication between workers inside and outside the siphon was maintained using two-way radios. The inspection was completed over five days, working first up the east slope, then along the bottom of the siphon while the working stage was moved to the west side, then finally up the west slope.

To aid the recording of observations on a pipe-by-pipe basis, 8½ x 11 mapping forms depicting at least two pipes each were prepared for the entire siphon (Figure 2). Maps included a one-foot longitudinal by 6-inch circumferential grid pattern with clock reference for mapping the

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locations of pipe defects and other observations (Figure 3). Pipeline information listed on each map included horizontal stationing for each joint, USBR and EM Inspection Contractor pipe numbers, pipe material type (PCCP or steel), PCCP pressure class, welded joint locations, and approximate locations of pipe anchors and collars on the exterior of the pipeline. Mapping the siphon using these forms enabled better work planning and progress monitoring and facilitated the assessment phase of the investigation.

Figure 3 – Clock Reference for Recording Observations.

INSPECTION FINDINGS

The overall condition of the North Fork Siphon was determined to be considerably worse than was anticipated based on the findings of the earlier inspections: 196 pipes exhibited serious defects, with 24 having structural defects indicative of incipient failure; nearly 1,600 cracks were mapped. The inspection findings are summarized in Table 1.

There appeared to be some correlation between the pipe anchors/collars on the exterior of the siphon and cracks observed on the interior, with cracks and crack systems correlating with almost 60% of the anchor/collar locations. The original design notes for the siphon were not available for this assessment; however, if the siphon was not designed to accommodate the non-axial stresses imposed by the steep slopes and the anchors/collars, longitudinal and circumferential cracking of the pipe barrels proximal to the anchor/collar locations could occur.

Many of the observed defects appeared to be related to poor manufacturing and quality control practices during pipe fabrication. For example, air entrapment and poor consolidation of concrete during pours may have created voids and cement-lean pockets, which would tend to develop inadequate bond to the steel (Figure 4). Some pipes exhibited excessive surface erosion while adjacent pipes exhibited no such condition; which indicated the core of the eroded pipes was less durable. In some cases the erosion revealed circumferential stratification in the core aggregate, which suggests the concrete was not well mixed when poured. Finally, foreign material including wood debris and “domestic” garbage was found embedded in some pipes.

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Table 1 – Summary of Inspection Findings.

Defect	Defect Count	Comment
Cracks in Barrels		
Longitudinal	22	One is full pipe; one is nearly full pipe
Circumferential	~274	36 spirals or systems that are complete or near complete circumference
Multiple Circ.	> 983	Occur on lower third of pipe circumference
Cracks Near Joints		
Joint Crack	139	119 complete or near-complete circumference
Spigot Crack	184	22 complete or near-complete circumference
Hollows	121	Range from small to very large
Joint Spalls	> 47	38 joints affected
Pipe Spalls	15	In bell or pipe barrel
Leaching	> 69	Efflorescence
Damp Joints	4	At low point and on east slope

Figure 4 –Honeycombed Mortar Around Joint Ring of Surplus PCCP.

CONDITION ASSESSMENT

This inspection revealed considerable evidence that the overall condition of the siphon was

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not good. Based on the types and spatial extent of defects observed throughout the siphon, it was appropriate to conclude that many of the PCCP pipes were near the end of their remaining useful service life and many were at increased risk of further deterioration.

Table 2 –Structural Pipe/Joint Defect Rating System.

Rating	Implication	Typical Description
5	Incipient Failure	- Large hollows > 4” in any dimension - Pronounced 4-point longitudinal cracking > 0.01” - Loss of lining due to cracking
4	Serious Defects - Incipient Failure Possible	- Crown/Invert longitudinal cracks > 0.01” - 4-point longitudinal cracking approaching 0.01” - Multiple crack patterns - Hollows – minor = < 4” in any dimension - Severe loss of internal mortar at joint - Circ. cracks > 0.01” where cylinder is visible - Complete loss of grout at joint
3	Moderate defects – further deterioration likely	- Circ. cracks greater than 0.01” (barrel or joint) - Longitudinal cracks < 0.01”
2	Minor defects – low probability for further deterioration	- Circ. cracks only (barrel or joint related) - Crack width less than 0.01”
1	No Defects	No Defects

The abundance of cracks and hollow-sounding areas in the pipes imply not only is there a lack of compression of the concrete core due to relaxation or failure of the prestressed wires, but also of a heightened risk of corrosion for the underlying steel components. While not all cracks will lead to corrosion of the underlying steel, experience has shown that even small cracks within conventional service crack widths may still facilitate corrosion processes where the core has disbonded from the cylinder.

Five-point rating systems were developed to analyze and assess the condition of the siphon based on three categories of defects: structural defects, joint defects and erosion/wear. The rating systems are shown in Table 2 and Table 3.

The overall condition rating for a pipe is based on the highest rating for any structural, joint and erosion defects observed in that pipe. Any pipe with a rating of 3 or higher would be of concern, with risk of failure increasing as the rating approaches 5.

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Table 3 – Erosion/Wear Defect Rating System.

Rating	Implication	Typical Description
5	Interior lining failed	- Lining failures - Full depth loss of lining due to erosion / wear - Cylinder visible
4	Serious wear - Incipient lining Failure	- Serious loss of lining - Aggregate visible with pronounced profile - Cylinder not yet visible
3	Moderate wear – progressive action and will continue	- Moderate loss of fines – aggregate profile visible
2	Minor wear – not likely an active process	- Surface loss of fines in lining
1	No Wear	- No wear

Of 233 PCCP pipes inspected, 207 (89%) were rated 3 or higher, 196 (84%) were rated 4 or higher, and 59 (25%) were rated 5, with 24 (10%) of those being rated 5 for structural defects. All categories of pipes were scattered throughout the siphon.

The presence of longitudinal cracks in the pipe core indicates a loss of compression across a series of prestressed wires (wire break zone) and is an indication that wires have yielded or broken. Longitudinal cracks were detected in 19 pipes, three of which exhibited two longitudinal cracks each. As the length of the wire break zone approaches pipe radius, there is a risk of near-term failure. Five pipes exhibited longitudinal cracks that exceeded pipe radius by roughly 10% to 230%. All of these longitudinally-cracked pipes would be recommended for replacement.

Sounding detected 121 hollow areas in 91 pipes, the vast majority (95%) occurring at or near the pipe spigot. Fifty-nine of these (65%) were accompanied by partial or complete circumferential cracks that were associated with the spigot joint ring (the cracks tended to occur about 4 to 6 inches from the joint). Ten hollow areas extended beyond the immediate spigot area, and in two pipes near the top of the west slope these areas were large and extended far into the pipe barrel along the invert.

OPTIONS FOR MANAGING THE SIPHON

The following were presented as options for managing the operation and rehabilitation of the siphon.

Operations: The first concern of the CUWCD would be to address means to mitigate operations that may result in near-term loss of service. PCCP performs best when operated at a constant pressure. However, the siphon is occasionally dewatered to enable maintenance or inspection activities, which results in the prestressed wires being relaxed when the pipe is dewatered, and strained when the pipe is refilled. Cyclic operation of PCCP tends to shorten the life of the wires. Adopting operating procedures that minimize cycling and maintain steady flow and pressure within the siphon would be beneficial.

Rehabilitation or Replacement: Structural rehabilitation, removal and replacement of deteriorated pipes, and complete replacement of the entire siphon were all options for managing the siphon. However, structural rehabilitation and replacement of deteriorated sections are very time-consuming efforts that may take more time to execute than was reasonable to keep the siphon out of service.

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Limited structural rehabilitation of the worst sections using internal liners to extend the useful life of the siphon was also an option. At the time of this assessment, a subcommittee of the American Water Works Association (AWWA) Concrete Pressure Pipe Committee was developing a standard for the repair of PCCP using carbon fiber reinforced polymer (CFRP) liners, and the interim guidelines could have been utilized to guide this rehabilitation. However, the draft standard did not address all of the technical challenges attendant with that type of repair. Failures of un-repaired PCCP immediately adjacent to PCCP repaired with CFRP have occurred and were a legitimate concern in this case due to the widespread presence of defects that facilitated further deterioration processes.

Alternately, the siphon could be repaired by inserting a steel cylinder along the entire length of the siphon. The split-cylinder method has been used by many Western U.S. water agencies; however, it results in a reduced inside diameter and construction may take as much time as the original pipeline construction (two seasons). Once repaired in that manner it is supposed that a doubling of the siphon's service life may be achieved; however, since it is a repaired rather than new product, and shortcomings in the original siphon design regarding potential for differential settlement on a steep slope may not be resolved by this method.

Considering long-term reliability, planning for a new siphon parallel to the existing siphon was also an option. The construction of a parallel pipeline would allow the existing siphon to remain in service during construction activities. Should this be the desired option, it was recommended that the appropriate engineering studies be commenced to replace the existing North Fork Siphon.

Further Investigation and Monitoring: Acoustic monitoring of the siphon to enable detection of new wire breaks would be useful, both for determining if the reinstatement of the line following the inspection caused any further damage (wire breaks) and for remotely alerting CUWCD of a pipe failure, should one occur.

External inspections and petrographic testing of mortar and concrete samples, removal of coating to inspect wire, and other external forensic evaluation of the pipe could be considered, particularly at pipes where significant evidence of distress is apparent, to obtain additional information to support the rehabilitation or replacement decision-making process.

CONCLUSIONS

The 72-inch diameter North Fork Siphon, with laying length of 4,750 feet, a vertical elevation difference of 716 feet, and an inclination in places up to 70% was inspected by man-entry methods during November 16-20, 2016. The inspection used a balance of sounding and visual data capture but followed the protocol of ACI 201.1R-08.

The results of the inspection revealed considerably more defects than were observed in EM and sounding surveys carried out in 2009 and 2014. 196 pipes (out of 233 total pipes inspected) exhibited defects that were indicative of active deterioration processes being present, with 24 of those having structural defects indicative of incipient failure. In all, nearly 1,600 crack defects were mapped in 233 pipes.

Due to the spatial extent and severity of the damage observed throughout the siphon, as well as its operating constraints, it was decided to replace the siphon in its entirety as opposed to undertaking localized or widespread rehabilitation. Measures to reduce risk of inadvertent failure during operation prior to final repairs being undertaken were presented. Planning and design for the new siphon are presently underway.

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APPENDIX C:
PROFILER EM™ EMP 400 BROCHURE

Multi-Frequency EM Conductivity Meter

Profiler™ EMP-400

www.geophysical.com

The Profiler™ EMP-400 is GSSI's powerful electromagnetic induction tool. This EM system was built from the ground up using a proprietary source cancellation and calibration system to create superior signal stability at an affordable price.

Typical Uses

- Environmental assessment
- Archaeology
- Geological investigation
- Site assessment
- Ground water investigation
- Agricultural research

Acquire Data

- User-friendly system
- Unmatched signal stability
- Multi-frequency system

Deliver Results

- Flexible battery options
- Advanced software features for real-time data results
- Files are stored on internal memory and structured in Excel format

Premium Mobility

- Lightweight – weighs under 10 pounds
- Wireless data logger eliminates cable noise
- Integrated GPS
- Environmentally sealed system that is durable and easy to transport

"The GSSI Profiler EMP-400 is a valuable tool that provides our clients with more efficient and comprehensive geophysical surveys. We have been impressed with its simplicity to deploy in the field and the data it outputs to create an easy to understand sub-surface image of our geophysical survey areas."

Fletcher S. Thompson, E.F. Thompson Geotechnologies, Inc.

Profiler Solutions

Geophysical, agricultural and environmental professionals require a reliable and accurate means to examine soil conditions and structures found beneath the surface of the earth. GSSI's GPR and EM instruments have long been the choice for geophysical investigations with a wide range of high precision, field proven tools.

Picture shows complementary GPR system, UtilityScan™

Versatility and Functionality

The Profiler EMP-400 is a frequency domain, electromagnetic profiling system. By acquiring multiple frequencies, the user can select the frequencies that provide the best results for a specific application.

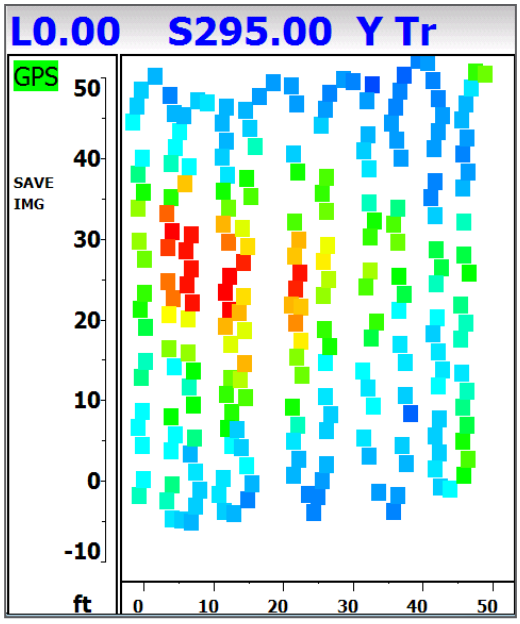
The Profiler system's mechanical structure and electronics are designed for maximum structural and thermal stability. These key features minimize signal drift and maintain an accurate zero level and system null across the full bandwidth of the system.

Advanced software features offer the user several options to view the data, thereby enhancing survey efficiency. The "freeway" collection mode allows the user to collect un-gridded data by using GPS coordinates as reference points. Users can freely roam the survey site without setting up a physical grid on the ground to collect data. The Profiler EMP-400 also provides real-time data output via a color-coded map, which enables the user to quickly and easily identify areas of interest on site.

Partnering GPR and EM Technology

Use GSSI's Profiler EMP-400 as a stand-alone geophysical instrument or as a complementary tool to our GPR products. Many companies find EM to be an effective survey method for large-scale environmental assessments, such as UST and drum locating, plume mapping and landfill delineation.

By using the Profiler as a quick reconnaissance level survey tool, users are better apt to narrow down areas of interest on large survey sites and use GPR to concentrate on anomalies.

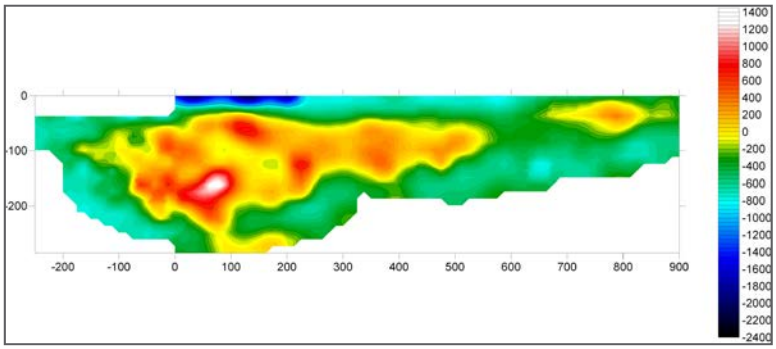


Data illustrates freeway collection mode using the real-time color-coded mapping feature.

Data Solutions

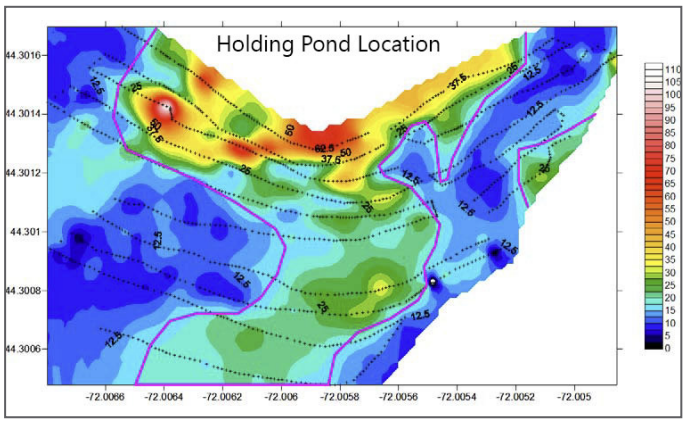
The Profiler can be configured to simultaneously measure up to 3 frequencies from 1000 Hz to16,000 Hz. The system can be deployed in either the vertical or horizontal dipole mode.

Landfill Delineation



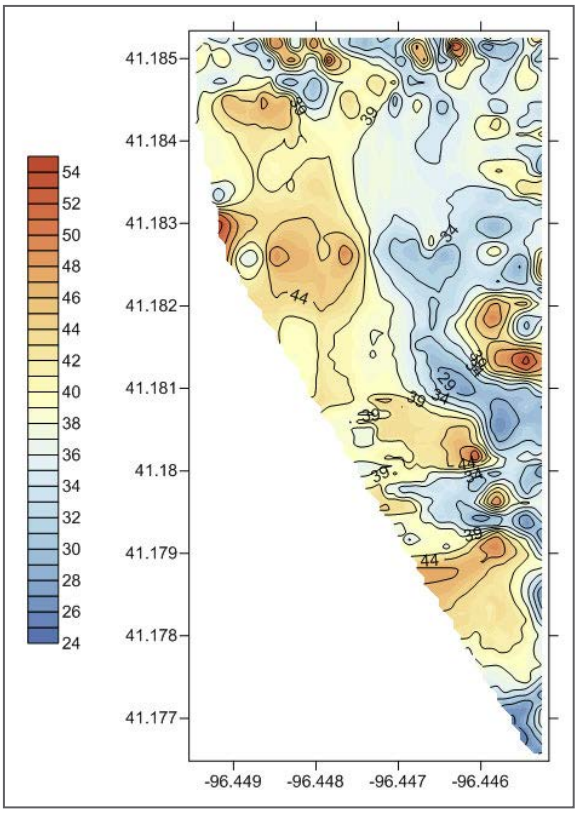
Soil conductivity map of a former landfill site indicating lateral extent of areas of high conductivity caused by landfill refuse.

Environmental Assessment



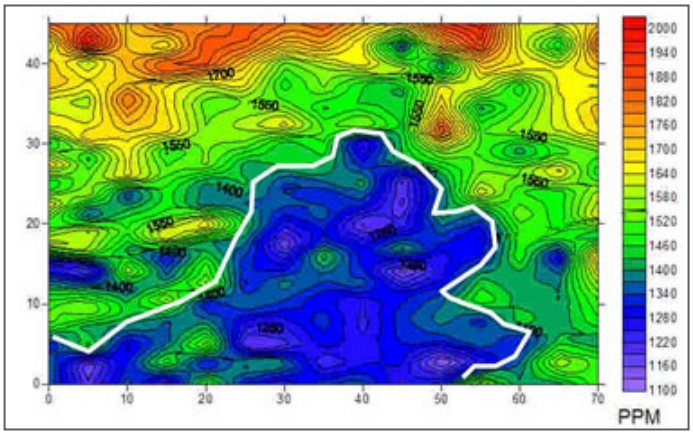
Profiler EM color contour plots showing the ability of the system to map potential plumes related to changes in soil conductivity. The data, collected at 15 kHz conductivity, illustrates a leachate plume from a holding pond represented by the pink outline.

Precision Agriculture



GSSI Profiler EMP-400 16 kHz conductivity plot showing variations in soil texture & moisture holding capacity at a known test plot. Data was collected with the system towed behind an ATV – note GPS positioning. Scale to the left shows the values represented in mS/m.

Geological Investigation



Data illustrates the lateral extents of a resistive anomaly common to sinkhole geology.

Electromagnetic Induction Method Explained

EM instruments contain two sets of coils that are located on opposite ends of the tool. One set of coils is used to transmit a primary magnetic field, which generates an electrical current into the ground. The induced current then generates a secondary magnetic field, which is sensed by the coils in the receiver end of the instrument. Data is then displayed on a control unit indicating the conductivity of the earth.

EM Equipment

The Profiler system is made up of two main components:

1 EM instrument; which is comprised of the transmitter (a), receiver (b) and electronics enclosure (c)

2 PDA; the instrument interface

System Specifications	
Coil Spacing	4 ft (1.21 m)
Operational Bandwidth	1 kHz to 16 kHz
Memory	248.5 MB 180,000 continuous data points 360,000 discrete data points
Power	Re-chargeable Lithium Ion battery or 4 (four) AA batteries
Data Transfer	by Microsoft ActiveSync or Device Manager via USB cable
Display	2.2 x 2.9 in (5.58 x 7.36 cm) color screen
Records up to 3 frequencies simultaneously	Measurement values: In-phase: PPM Quadrature: PPM Conductivity: mS/m
Mechanical	
Dimensions	57.5 (l) x 9.5 (w) x 4.9 (h) in (1.46 m x 24 cm x 12.4 cm)
Weight	9.9 lbs (4.5 kg)
Environmental	Water resistant

System Includes

- Profiler™ EMP-400 System with rugged, wireless data logger
- 20-channel WAAS GPS
- Batteries
- Battery chargers
- Carrying strap and low-carry handle
- Rugged transit case
- Instruction manual and Utilities CD

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