Miami Dade Water and Sewer Department
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2011 Annual Water Loss Reduction Plan Implementation Status Report

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1. Introduction

The South Florida Water Management District (SFWMD or District) requires Miami-Dade Water and Sewer Department (MDWASD) to prepare an annual status report of its 20-year Water Loss Reduction Plan (the Plan) implementation, per Limiting Condition 49 of the Miami-Dade County Water Use Permit (WUP). MDWASD retained Malcolm Pirnie, Inc. to prepare the 2011 Annual Water Loss Reduction Plan Implementation Status Report (2011 Annual Status Report) and provide assistance with the Plan implementation in 2012. This document is the 2011 Annual Status Report, which includes water audits as required by Limiting Condition 49.

1.1. Background and Scope of Work

MDWASD's 20-year Water Loss Reduction Plan was based on an evaluation of MDWASD's water supply and demand for Fiscal Year (FY) 2005. In May 2007, the SFWMD approved the Plan and issued a 20-year WUP on November 15, 2007. The WUP was later revised in November 2010 with an expiration date of November 3, 2030. The revised WUP is included in Appendix A.

The Plan recommended real and apparent water loss mitigation approaches over the next 20 years with corresponding budget and implementation schedule recommendations. The recommended schedules of the real and apparent water loss reduction activities are presented in Tables 1-1 and 1-2. These tables are the same as Exhibits 17A and 17B of the revised WUP. The tables also provide the anticipated annual water savings and associated annual value of water savings for the water loss reduction activities.

Limiting Condition 49 of the revised WUP specifically applies to implementation of the approved Water Loss Reduction Plan. Key requirements of Limiting Condition 49 are:

- Quarterly determination of distribution system losses
- Annual reporting of distribution system losses on March 15th of each year for the previous calendar year
- Determination of losses in each water treatment plant (WTP)
- Water audits in accordance with IWA/AWWA standard methodologies
- Planned annual reporting of water loss reduction activities and expenditures, along with associated water savings for the subsequent calendar year
- Annual reporting of water loss reduction trends and changes from the previous year
- Annual reporting of additional water loss reduction activities if water losses as defined by AWWA methodology exceed ten percent.

Table 1-1: Schedule of Real Water Loss Reduction Activities (Exhibit 17A) January 2007 through December 2026

Activity	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
5.3 Recommendations for Real Loss Reduction										
5.3.1 System Design (Active Review)	▨	▨								
5.3.2 System Management										
5.3.2.3 Asset Maintenance or Replacement			▨	▨	▨	▨	▨	▨	▨	▨
5.3.2.4 Reduce Maintenance Response Times	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
5.3.2.5 Active Leakage Control and Sounding	▨	▨ Pilot	▨	▨	▨	▨	▨	▨	▨	▨
5.3.2.7 Pressure Management			▨	▨	▨	▨	▨	▨	▨	▨
5.3.2.8 Speed and Quality of Repairs	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Perform Venturi Comparative Tests-WTPs		■	■	■						
Perform Venturi Comparative Tests-wholesale customers	▨	■	■	■						
Conduct wholesale customer unmetered connection survey	▨	▨								
Pilot Fixed Network AMR		▨ Pilot								
Enhance GIS database	▨	▨								
ANNUAL WATER SAVINGS (Million Gallons)				650	1300	1950	2600	3250	3900	4550
ANNUAL VALUE OF WATER SAVINGS (Million $)				$0.297	$0.595	$0.892	$1.189	$1.487	$1.784	$2.081

Activity	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
5.3 Recommendations for Real Loss Reduction										
5.3.1 System Design (Active Review)										
5.3.2 System Management	▨									
5.3.2.3 Asset Maintenance or Replacement	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
5.3.2.4 Reduce Maintenance Response Times	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
5.3.2.5 Active Leakage Control and Sounding	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
5.3.2.7 Pressure Management	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
5.3.2.8 Speed and Quality of Repairs	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Achieve target real loss of 5 billion gallons per year	X									
Achieve target Infrastructure Leakage Index (ILI) of 3.0	X									
ANNUAL WATER SAVINGS (Million Gallons)	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200
ANNUAL VALUE OF WATER SAVINGS (Million $)	$2.378	$2.378	$2.378	$2.378	$2.378	$2.378	$2.378	$2.378	$2.378	$2.378

Table 1-2: Schedule of Apparent Water Loss Reduction Activities (Exhibit 17B) January 2007 through December 2026

Activity	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
6.3 Recommendations for Apparent Water Loss Reduction										
6.3.1 Reducing Unmetered Supplies	▨	▨								
6.3.2 Improved Meter Accuracy		▨	▨	▨	▨	▨	▨	▨	▨	▨
6.3.3 Commercial Meter Types and Sizes		▨	▨	▨						
6.3.3.2.1 Compound Meters Usage Compared to Same Size Turbine Meters						Pilot				
6.3.3.3 Looking Forward (setting Economic Meter Testing Goals)		▨								
6.3.4 Improved Calibration of Wholesale Customer Meters	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
6.3.5 Wholesale Customer Unmetered Connection Analysis	▨	▨								
Conduct field accuracy testing of commercial meters	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Pilot AMR to improve data handling and reduce labor cost		Pilot								
Characterize residential water demand pattern		■								
Determine economic optimum for residential meter replacement		▨								
ANNUAL WATER SAVINGS (Million Gallons)				400	800	1200	1600	2000	2400	2800
ANNUAL VALUE OF WATER SAVINGS (Million $)				0.788	1.576	2.364	3.152	3.94	4.728	5.516

Activity	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
6.3 Recommendations for Apparent Water Loss Reduction										
6.3.1 Reducing Unmetered Supplies										
6.3.2 Improved Meter Accuracy	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
6.3.3 Commercial Meter Types and Sizes										
6.3.3.2.1 Compound Meters Usage Compared to Same Size Turbine Meters										
6.3.3.3 Looking Forward (setting Economic Meter Testing Goals)										
6.3.4 Improved Calibration of Wholesale Customer Meters	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
6.3.5 Wholesale Customer Unmetered Connection Analysis										
Conduct field accuracy testing of commercial meters	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Reduce Apparent Losses to 10 billion gallons per year										X
ANNUAL WATER SAVINGS (Million Gallons)	3200	3600	4000	4400	4800	5200	5600	6000	6400	6800
ANNUAL VALUE OF WATER SAVINGS (Million $)	6.304	7.092	7.88	8.668	9.456	10.244	11.032	11.82	12.608	13.396

Since 2008, Malcolm Pirnie, Inc. has been assisting MDWASD with the implementation of the 20-year Water Loss Reduction Plan to comply with applicable Limiting Conditions of the WUP. The intent of this effort is to perform water system audits and develop the 2011 Annual Status Report that is due to the South Florida Water Management District on March 15, 2012.

This report (2011 Annual Status Report) is divided into the following sections:

- Section 1 – presents the background and context of this annual required report and the specific scope of work elements conditional to the WUP.
- Section 2 – presents the water loss reduction activities that were performed in 2011.
- Section 3 – presents the IWA/AWWA distribution system water loss audits for calendar year (CY) 2011.
- Section 4 – presents the water loss audits for each of the MDWASD's WTPs for CY 2011.
- Section 5 – presents the status of the Water Loss Reduction Plan implementation and action items for FY 2012.

2. 2011 Water Loss Reduction Plan Activities

In 2011, ARCADIS/Malcolm Pirnie assisted MDWASD with the implementation of the 20-year Water Loss Reduction Plan in order to comply with the WUP. The tasks below describe the extent of the Plan implementation in 2011. Follow-up (and deferred) activities for 2012 are indicated, where applicable.

2.1. Real Water Loss Reduction Plan Tasks

The following are the tasks related to the MDWASD distribution system real water loss reduction plan that were accomplished in 2011. It should be noted that the tasks 2.1.1 and 2.1.2 listed below address annual requirements that are needed to be performed every year in accordance with the WUP.

2.1.1. Water Audits Using the IWA/AWWA Methodology

Water system audits for Calendar Year (CY) 2010 were prepared last year (in 2011) using the IWA/AWWA standardized software available free through the AWWA. The water audits for 2010 indicated an improvement trend in Infrastructure Leakage Index (ILI), which is a performance indicator for the distribution system calculated by the IWA/AWWA Water Audit Software. However the real losses and non-revenue water showed an increased trend in 2010. The 2010 Annual Water Loss Reduction Plan Implementation Status Report indicated that the increase in real losses in 2010 was due to large diameter main breaks and increased distribution system pressure which would increase water losses through the existing leaks. MDWASD performed a condition assessment of large diameter water mains in order to diagnose and prevent future water main breaks and water losses through main breaks.

The decrease in ILI in 2010 was attributed to availability of more refined pressure data and other improvements made by MDWASD in the reduction of distribution system losses. It should be noted that the IWA/AWWA water audits for CY 2011 are presented in Section 3 of this report.

2.1.2. Water Treatment Plant Audits

The individual water treatment plant water audits for CY 2010 were prepared last year by comparing the individual metered water flows pumped from the wells tributary to a water treatment plant and the water flows into and out of the specific water treatment plant. Below is a brief description of the results of water audits that were performed for 2011. The results of the water treatment plant audits that were performed for 2011 are presented in Section 4 of this report.

Raw-water well meter readings were on average 15 percent less than the raw-water influent meter readings at the Hialeah/Preston WTP and only one percent less than the raw-water influent meter readings at the Alexander Orr WTP. In 2011, MDWASD replaced all of the raw water well meters (a total of 35) at the Alexander Orr WTP wellfields. MDWASD planned to investigate and, where possible, address identified conditions (meter calibration / configuration or real losses) that contribute to the noted disparity at Hialeah/Preston. The difference in well supply and influent meter readings at Hialeah/Preston are increasing and can be attributed to both under-registering well meters and over-registering Venturi influent meters.

Based on the raw-water influent and finished-water effluent metered flows at the Alexander Orr WTP, in-plant water losses were estimated to be approximately 12 percent for 2011. The 2009 Annual Status Report indicated that correcting the apparent raw-water influent and finished-water effluent Venturi meter inaccuracies at the Alexander Orr WTP would eliminate (or reduce) the “apparent” water losses miscounted as “in-plant” water losses.

Applying the 2009 raw water meter adjustment reduction and the finished water meter adjustment increase resulted in a reasonable in-plant loss for the Alexander Orr WTP in 2010. Applying these adjustment factors for the 2010 influent and effluent data did not yield a similar result. With added adjustment factors, the estimated production of finished water at Orr was 12 percent greater than the measured influent flow. As discussed in Section 4, this result emphasizes the need for meter calibration and accuracy testing more frequently at the treatment plants. Since production input data is critical to the IWA/AWWA water audit results, validating this data adds credibility to the monitoring of progress in water loss reduction over time. Overestimating production amounts at water treatment plants results in over-stating losses, since a larger difference in production and metered customer demand occurs.

Based on the raw-water and finished-water metered flows at the Hialeah/Preston WTP, in-plant water losses were estimated to be approximately 3 percent. Improvement is notable in 2011 over 2010 results of six percent.

2.1.3. Implementation of Enhanced and Effective Leak Detection Program

MDWASD has one of the best leak detection programs of all water utilities in the U.S. MDWASD still continues to introduce changes and modifications to its program in order to enhance the efficiency of the leak detection program. In 2010, MDWASD tested distribution system leak detection sensors called “Permalogs” (by Sensus) and “Mlogs” (by Itron). However, pilot tests with the new leak detection sensors did not yield satisfactory results. Therefore, MDWASD did not proceed with the full-scale implementation of the new sensors.

In 2009, MDWASD (through Malcolm Pirnie, Inc.) evaluated analytical techniques that establish an economic balance between the costs of leakage control and the benefits that accrue from real water savings and enhanced effectiveness of the leak detection program and pipe replacement program. In 2010, an ‘Economic Analyses of Leak Detection Program and Pipe Replacement’ study was performed and documented. The study recommended targeting leakage reduction based on largest volume savings per dollar spent and periodically re-evaluating economics to determine cost-effective leak mitigation approaches. In 2011, MDWASD implemented the recommendations of the study to the existing leak detection program. Water losses from water main leaks have decreased about 10 percent when compared to those in 2010, part of which could be attributed to the implementation of an enhanced and effective leak detection program.

2.2. Apparent Water Loss Reduction Plan Tasks

The following are the tasks related to MDWASD's distribution system apparent water loss reduction that were developed in 2011. Tasks 2.2.1 and 2.2.2 listed below address annual requirements and, therefore, need to be performed every year in accordance with WUP. The other tasks have led to follow-up activities that would be continued in the future upon the implementation of other tasks.

2.2.1. Accounting of Fire Department Water Usage

In 2010, MDWASD identified the contacts of each Fire Department that uses water from MDWASD facilities. The Fire Departments were informed of MDWASD's plans to appropriately account for the fire department water usage. In 2012, a meeting will be held with the identified Fire Departments to evaluate different water usage activities. In cooperation with these Fire Departments, a methodology for appropriately accounting for fire department water usage will be developed (follow up).

2.2.2. Meter Sizing Criteria

In 2010, MDWASD developed appropriate meter sizing criteria and protocols in accordance with anticipated water demand, water demand profile, meter location, meter setting design requirement, and service line specifications. The criteria and protocols developed were consistent with AWWA standards (as identified in AWWA Manual M22). Recommendations were provided for residential (single family and multi-unit), commercial, and industrial meters.

Currently, the meter sizing and selection decision is at the discretion of the building designer based on obtained estimated peak demand calculated through AWWA Manual M22. The 2010 meter sizing criteria report recommended an additional form-based policy that requires demand be itemized in a worksheet to be approved by MDWASD based on the fixture value method. The worksheet would remove potential ambiguities in meter size and selection and minimize over-sizing or under-sizing of meters. By appropriately sizing meters, potential apparent losses caused by under-metered flows could be reduced.

In addition, the worksheet would reflect a more standardized method of meter selection and size consistent with the existing AWWA methodology. This would allow MDWASD to accomplish greater control over the meter sizing process with minimal additional effort. If appropriately exercised, revenue may increase due to improved registration of low flow. However, it was recommended that the meter sizing method be updated as better protocols become available.

2.2.3. Summary of Water Loss Reduction Activities

A summary table (Table 5-1 in Section 5) with a list of action items that were required to be developed or implemented in 2011 as per the WUP limiting conditions was prepared. The table described the status of action items, activities that were performed, and recommended follow-up activities for each action item.

2.2.4. Annual Status Report

The Annual Status Report with summary and supporting data for the water loss reduction activities performed in the year 2010 was prepared in March 2011 to fulfill the requirement of the WUP.

2.3. Highlights of the 2011 Water Loss Reduction Activities

2.3.1. AMR Implementation

MDWASD installed approximately 1,000 residential water meters (500 using Itron radio endpoints and 500 using Sensus Flexnet radio endpoints) operating under fixed network Advanced Metering Infrastructure (AMI) systems that were installed in MDWASD's service area as part of the Automated Meter Reading (AMR) pilot implementation performed in 2009. In 2010, MDWASD monitored and estimated the water savings that resulted from the operation of the AMI system. It was indicated by MDWASD that 5.69 million gallons per year (MGY) of water savings were achieved with the implementation of the AMI system.

In 2010, MDWASD initiated the expansion of the AMI network. An additional 200 Sensus AMI meters and radio endpoints were installed on large commercial accounts. An additional 50 commercial Sensus AMI meters were installed in the Miami-Dade downtown area. A second pilot study is underway with the installation of additional residential and commercial meters and endpoints. Also, 4,000 AMI meters are being installed in the City of Miami Springs service area. These meters will be online by the end of the 2012 Fiscal Year.

MDWASD plans to continue expanding its AMI network in future years for increased water savings and to utilize functional capabilities of AMI systems in customer water use characterization, water conservation, improved customer service, noise monitoring and leak detection, better management of system operations and planning, and monthly billing.

2.3.2. PCCP Pipe Condition Assessments Program

On March 2, 2010 there was a 54-inch Pre-stressed Concrete Cylinder Pipe (PCCP) break in the City of Hialeah. In response to pipeline breaks in 2008 and in 2010, MDWASD initiated a PCCP condition assessment program through contracting with Pure Technologies. The following are the activities that were performed as part of this program:

- An initial assessment of a one-mile PCCP pipe segment that was isolated for initial repair revealed the following immediate needs:

  - 46 pipe segments of a total of 256 pipe segments assessed had broken pre-stressed wire, of which 17 had broken pipes throughout the pipe segment. Consequently, 24 pipe segments were recommended for immediate repair.
- A second survey of 16.3 miles of PCCP from Preston WTP to N.W. 191st Street and N.W. 18th Avenue, using a pipe diver, in order to the maintain the pipe in service, revealed the following needs:
  - 126 pipe segments of a total of 4,505 pipe segments assessed had at least 5 wire breaks, of which 40 pipe segments had broken pipes throughout the pipe segment. Consequently, 49 pipe segments were recommended for immediate repair.
- Confirmatory testing using a pipe diver, robot and continuity testing, and forensic investigation was conducted on the 54-inch main:
  - The testing confirmed that the pipes were properly identified for repair.
  - Visual and sound inspections were performed to confirm the electromagnetic survey results.
  - Longitudinal cracks and audible delamination were identified on 2 of 3 of the most severely distressed pipes. Wire continuity testing was performed on the third pipe.
- A rehabilitation program using Carbon Fiber Reinforced Plastic (CFRP) system was developed:
  - As part of the rehabilitation program that was performed in 2010, 40 miles of PCCP was inspected (budgeted for $10 M). It was estimated by MDWASD that 2 to 4 mgd of water was lost in leaks through the following identified pipes:
    - 8.5 miles of 96-inch raw water main were found to have 9 bad joints.
    - 10 miles of 48-inch pipe were found to have 4 bad sections.
    - Rehabilitation work on the 96-inch and 48-inch mains is still pending.
  - As part of the future rehabilitation program, 15 miles of PCCP pipe per year will be inspected using electromagnetic methods (budgeted for $1.8M per mile of pipe). All 36-inch pipe will be inspected over a 3-year period. The prioritization for the inspection will be based on risk rating with respect to:
    - Operating pressure
    - Diameter
    - Age
    - Land-use
    - Operational criticality/consequence of failure

- Repair history
- Date last inspected

In November 2011, Pure Technologies submitted its final report to MDWASD on its “Condition Assessment of Prestressed Concrete Cylinder Pipe”, attached hereto as Appendix C. This report summarizes field and laboratory testing results for three major water transmission pipelines in the MDWASD delivery system, including the following:

48-inch SW Well Field Supply Main

60-inch SW Well Field Supply Main

72-inch SW 64th Street Transmission Main

These three pipe segments are constructed of prestressed concrete cylinder pipe, similar to the material in the 2010 evaluation. These segments were inspected and their condition assessed using multiple testing methodologies in April and May 2011. General observations for each of the tested pipelines are:

<u>48-inch SW Well Field Supply Main</u>

An internal inspection was performed using an electromagnetic survey of 1,228 pipes for 3.69 miles. Only 2 pipes indicated broken wire wraps. The SmartBall leak detection survey indicated no leaks in the main at this time.

<u>60-inch SW Well Field Supply Main</u>

An internal inspection was performed using an electromagnetic survey of 954 pipes for 3.48 miles. Twenty one pipes indicated broken wire wraps. The SmartBall leak detection survey indicated no leaks in this main at this time.

<u>72-inch SW 64th Street Transmission Main</u>

An internal inspection was performed using an electromagnetic survey of 132 pipes for 0.47 miles. Six pipes had broken wire wraps. A SmartBall leak survey is planned for 2012.

The percent of distressed pipe varied from 0.2 on the 48-inch main to 4.5 on the 72-inch main.

Eight recommendations and conclusions were offered by Pure Technologies as a result of their multi-faceted PCCP testing program:

1. Rehabilitate or replace 3 pipes from the 60-inch main and 4 pipes from the 72-inch main. The rehabilitation should be through internal carbon fiber reinforcement.

2. Based on inspection and structural evaluation, there is a risk of PCCP failure.

3. A segment of the 72-inch main requires monitoring for broken wire wraps. The segment has 30 broken wire wraps and could reach a Yield Limit State if 37 wire wraps are broken for an 115 psi surge event.

4. Acoustic monitoring is recommended for mains having high consequence of failure. If no acoustic monitoring is implemented, re-inspection is recommended every three years.

5. If critical pipes are out of service, excavation and forensic evaluation are recommended to assess wire break damage.

6. Internal inspection of the 72-inch is recommended.

7. Pressure monitoring is suggested to detect potential surge conditions which adversely affect pipe integrity.

8. Leak detection surveys should be performed every three years, since leaks are precursors to pipe breaks and failures.

Pure Technologies concludes that following the above recommendations should result in a low probability of failure of the three segments tested within the next five years. Because of the utilization of MDWASD staff and resources to plan, coordinate, and perform the Pure Technologies pipeline testing program, some planned elements of the 20-year water loss reduction plan were reduced in scope and effort in this low-growth south Florida economy. The large diameter pipeline assessment program is a high priority and necessary activity of MDWASD as an important element of its real loss reduction plan.

2.4. Conclusions

Although the water loss reduction plan has been implemented in response to WUP requirements and significant unforeseen pipeline breakage events the last few years, MDWASD has made considerable progress in initiating the implementation of the Plan recommendations. In these early implementation years of the 20-year program, MDWASD has been focused on better quantifying the nature and extent of water supplies and demands through better metering and meter replacement and better estimation of real and apparent water losses. Better and more valid water supply and demand data will allow the utility to more strategically target and reduce water losses in the future. Current and additional strategies to reduce water losses that are recommended or underway are described in Section 5 of this report.

3. IWA/AWWA Water Audits

This Section presents the annual IWA/AWWA water distribution system audits that were performed in order to meet the requirements of Limiting Condition 49 of the MDWASD's Water Use Permit.

3.1. IWA/AWWA Water Loss Audits Results

IWA/AWWA water loss audit methodology was developed as a worldwide standard for water loss accounting to provide industry-standard benchmarks and allow for comparisons of water losses across different utilities. This methodology is considered to be a best management practice for controlling water loss. The audit is designed to address how much water is being lost in the utility and how much these losses are costing the utility.

As part of its ongoing water loss reduction plan, MDWASD has conducted "top down" IWA/AWWA water audits annually since 2005, as a way to benchmark the effectiveness of its program over time. A top-down approach to a water loss audit relies on gathering data from records, procedures, and other information systems for which data is readily available. The top-down method can provide a preliminary assessment of water loss. The top-down audit also helps to identify components that require further validation. Ultimately, the water auditor can better validate and improve the accuracy of the water audit when it is augmented by component analysis, bottom-up field measurements, or both. Table 3-1 presents the IWA/AWWA water audit components and definitions.

Table 3-1: Components and Definitions of the IWA/AWWA Water Balance

Water Balance Component	Definition
System Input Volume	The annual volume input (finished water) to the water distribution system.
Authorized Consumption	The annual volume of metered and/or unmetered water taken by registered customers, the water supplier, and others who are authorized to do so.
Water Losses	The difference between System Input Volume and Authorized Consumption, consisting of Apparent Losses plus Real Losses.
Apparent Losses	Includes Unauthorized Consumption, all types of customer metering inaccuracies, and data handling errors.
Real Losses	The annual volumes lost through all types of leaks, breaks and overflows on mains, service reservoirs and service connections up to the point of customer metering.
Revenue Water (or Billed Authorized Consumption)	Those components of System Input Volume which are billed and produce revenue.

Non-Revenue Water (NRW)	The difference between System Input Volume and Billed Authorized Consumption.

Source: AWWA M36 Manual

Water losses (apparent or real) occurring in a distribution system (leakage, water theft, and/or meter inaccuracy) result in a loss of revenue to the water utility. The higher the NRW, the more economically inefficient is the water utility. The goal of the water audit using the "top-down" approach is to determine the difference between the total quantity of water produced and the amount of water billed. A successful water audit accounts for all water losses. Therefore, there is no "unaccounted-for" water. A water audit provides the utility with detailed information about the distribution system and water users, leading towards better management of resources and, hence, an improved reliability.

With the help of a water audit, the amount of various types of losses can be determined or at least reasonably estimated, and the amount of revenue lost and energy costs wasted due to water loss can be calculated. Table 3-2 below summarizes the "Best Practice" standard water balance categories, based on the above definitions, calculated in the IWA/AWWA water loss audit. The water audit performance indicators give a reliable assessment of water loss standing from operational, financial, and water resources management perspectives. They are effective in evaluating current standing, benchmarking with other utilities, and for preliminary loss reduction target setting.

Table 3-2: The IWA "Best Practice" Water Balance Used in the Water Audit

Water From Own Sources	Water Exported	Billed Water Exported			Revenue Water
	Water Supplied to the Retail Customers	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption (Including Water Exported)	
				Billed Unmetered Consumption	
			Unbilled Authorized Consumption	Unbilled Unmetered Consumption	Non-Revenue Water (NRW)
				Unbilled Metered Consumption	
		Water Losses	Apparent Losses	Unauthorized Consumption	
				Customer Metering Inaccuracies	
				Data Handling Errors	
			Real Losses	Leakage on Transmission and/or Distribution Mains	
Water Imported				Leakage and Overflow at Utility's Storage Tanks	
				Leakage on Service Connections	

One of the performance indicators for the distribution system calculated by the IWA/AWWA Water Audit Software is the Infrastructure Leakage Index (ILI). The ILI is calculated by dividing the Calculated Annual Real Losses (CARL) in the distribution system by the Unavoidable

Annual Real Losses (UARL). The ILI value is a sound operational benchmark for control of real water loss when data has a high degree of accuracy and validity.

UARL is "a theoretical reference value representing the technical low limit of leakage that could be achieved if all of today's best technology could be successfully applied," according to the definition provided by the Version 4.2 Water Audit Software published by the AWWA Water Loss Control Committee. The UARL estimates measured frequencies, flow rates, and durations of background losses, and unreported leaks, as well as the relationship between pressure and leakage. An equation (also provided by the Water Audit Software) to estimate this value has been developed based on the length of mains in the distribution system (Lm), number of service connections (Nc), length of private pipe (i.e. service lines) (Lp), and distribution system operating pressure (P) in a system:

$$UARL\,(\text{gal/day}) = (5.41 * Lm + 0.15 * Nc + 7.51 * Lp) * P$$

The UARL is used as a benchmark to which a utility's actual real losses can be compared year-over-year, or which can be used to compare one utility's performance to another. As described above, the ratio between a utility's current real losses and the UARL is the ILI. The initial target value or range for the ILI is often established as a preliminary benchmark in the early stages of a water audit, and the target is refined as the leakage management program moves forward. The selection of ILI target ranges (goals) is generally based on water resources, operational, and financial considerations. ILI target ranges are generally 1.0-3.0, 3.0-5.0, and 5.0-8.0, as described in Table 3-3. Generally, estimates of the ILI become more accurate as more and better data become available. Another feature of the ILI is that it allows for comparison between different utilities.

Table 3-3: Guidance on Target Infrastructure Leakage Index (ILI)

Target ILI Range	Water Resources Considerations	Operational Considerations	Financial Considerations
1.0 – 3.0	Available resources are very limited and/or environmentally unsound to develop	Leakage above this level requires expansion to existing infrastructure and/or new water resources	Water resources are costly to develop or purchase; ability to raise revenue(rates) is limited
3.0 – 5.0	It is believed that sufficient water resources are available for long term needs, using good leakage control	Existing water supply infrastructure capability is sufficient to meet long-term demand, with good leakage control	Water Resources can be developed or purchased at reasonable expense; rates can be increased
5.0 – 8.0	Water resources are plentiful, reliable and easily extracted	Superior reliability, capacity, and integrity of infrastructure	Low water purchase cost; customer affordability is not an issue

As an initial target, one of MDWASD’s internal goals is to reduce the ILI to below 3.0. In the early stages of a utility’s water loss reduction program, changes in the ILI year-over-year may be significantly affected by changes in the type and quality of data collected as the program becomes established.

3.2. IWA/AWWA Water Loss Audit Data and Implementation

Calendar Year 2011 IWA/AWWA water loss audits were conducted using standardized software available through the AWWA (Version 4.2). Data was collected from sources relevant to the calendar year being audited and entered into the IWA/AWWA water audit software as described in Table 3-4. Since 2005, MDWASD has made considerable progress implementing several activities that could provide accurate and precise data for the preparation of the water audits and to decrease its non-revenue water. Below is a list of major items that were improved by MDWASD since 2005.

- The UARL, which serves as the denominator for the ILI, is sensitive to average distribution system pressure. MDWASD has been implementing procedures to better estimate the distribution system pressure. In the 2005 audit, the distribution system pressure was estimated based on a single value provided by MDWASD (55 psi). For the 2006 through 2009 audits, the average distribution system pressure estimated using the pressure data at four points spaced throughout the distribution system was provided by MDWASD. For subsequent water audits, system pressure was recorded hourly at 25 locations throughout the MDWASD distribution system. More sensors were located at the extremities of the system than near the plants or at some intermediate distance in order to better monitor areas that are more likely to experience low pressure issues. The pressure recorders were categorized into three groups based on their proximity in relation to the WTPs (at WTP, medium distance, and far ends). The pressures for each group were averaged, and then the averages were used to calculate an overall system average pressure. The system pressure for 2011 was estimated to be 65.2 psi, which is greater than the previous year estimate of 63.5 psi.

- In 2007, MDWASD upgraded all the wholesale meters (about 65) to electronic AMR (Automatic Meter Reading) meters, and since then, MDWASD has been testing and repairing (if needed) these meters 3 times a year, in order to accurately account for the water exported to other utilities.

- In 2009, MDWASD estimated the meter accuracies of the five Alexander Orr WTP finished water venturi meters and indicated an apparent water loss of approximately 2.4 percent out of the Alexander Orr finished water production (i.e. 96.75 percent average Alexander Orr finished water meter accuracy). Since then, the master meter inaccuracies for the Alexander Orr WTP have been accounted for in the IWA/AWWA water audits.

Table 3-4: IWA/AWWA Water Loss Audit Input Data

Input Data	Definition / Source
Water Supplied	
Volume from own sources	Finished water produced by MDWASD's WTPs.
Master meter error adjustment	Estimate of MDWASD's finished water master meters innacuracy. CY 2009 accuracy testing results of the Alexander Orr WTP finished-water meters (2.4% innacuracy, 97.05% accuracy) were accounted for. Accuracy tests of the Hialeah / Preston WTP finished-water meters are pending and therefore were not accounted for.
Water imported	Finished water purchased by MDWASD from the City of North Miami Beach and Homestead.
Water exported	Finished water sold by MDWASD to its fifteen water wholesale customers.
Authorized Consumption	
Billed metered	MDWASD retail billed and metered water - including residential, commercial, industrial, and irrigation customers.
Billed unmetered consumption	MDWASD currently does not have billed unmetered consumption.
Unbilled metered consumption	Includes water supplied to MDWASD facilities and cleaning gravity mains (Obtained from MDWASD's UFW loss historical table).
Unbilled unmetered consumption	Includes Fire Department water use and flushing (donations and distribution) obtained from MDWASD UFW loss historical tables.
Water Losses	
Unauthorized consumption	Includes unathorized water withdrawn from hydrants, illegal connections, bypasses to consumption meter or meter reading equipment tampering. Following AWWA recommendations, the overall retail unauthorized consumption was estimated as 0.25% of the volume from own sources.
Customer metering inaccuracies	Apparent water losses caused by collective under-registration of customer water meters. 4.5% was used as indicated by Water Meter Periodic Testing (PT) Program Evaluation that was performed by MDWASD in November 1995.
Systematic data handling errors	Apparent water losses caused by systematic data handling errors in the meter reading and billing system. Assumed to be 2.5 % of the finished water produced and purchased.
System Data	
Length of mains	Includes length of all transmission and distribution mains. 5,774 miles provided from MDWASD GIS data. Enhancements to the GIS database has been completed in 2010 with details on pipe age, length, and diameter information.

Number of active and inactive service connections	Includes number of water service connections
Average length of customer service line	Length of customer service line between the Utility's service connection (curbstop) and the meter. Assumed to be 12 ft as indicated in the Unaccounted Water Loss Reduction Plan (Feb 2007)
Average operating pressure	65.2 psi average pressure as indicated by MDWASD staff.
Cost Data	
Total annual cost of operating system	Includes cost of water system operations, maintenance, repayment of capital bonds for infrastucture expansion or improvement, employee salarees or benefits, materials, equipment, insurance, fees, administrative costs and other costs to sustain drinking water supply.
Customer retail unit cost	Weighted average of individual costs and number of customer accounts in each class. Calculated as annual retail revenue divided by annual retail sales volume.
Variable production cost	Estimated as total production cost of water (source of supply, power and pumping, and purification) divided by total volume of water supplied to the water distribution system including the imported water.

- In 2009, MDWASD conducted a pilot study for Advanced Metering Infrastructure (AMI) systems. In 2010 and 2011, MDWASD expanded the pilot project to other parts of its water service area. The AMI systems provide functional capabilities to read retail meters more efficiently and accurately. The details of the AMI pilot project are provided in Section 2 of this report.

- In 2011, MDWASD started installing more technologically advanced electromagnetic meters which provide extended accuracy ranges, but have no moving parts and require battery replacement every 5-10 years, depending on the meter size.

- In 2010, MDWASD enhanced its GIS database system with information on water main lengths, diameters, materials, and age. The updated water main length information was used in the water audits for 2010 and 2011.

- In order to maintain meter reading accuracies that account for water that is being supplied to retail customers and for water being exported to other utilities, MDWASD has the following meter management and testing programs currently in place:

    - Preventive maintenance program, that includes testing for accuracy and repair and/or replacement as needed, for retail meters, 5/8 inch to 1 inch in diameter, is performed every 8 years.

    - Preventive maintenance program, that includes testing for accuracy and repair and/or replacement as needed, 1 ½ inch to 2 inch in diameter, is performed every 4 years.

    - Retail meters larger than 2 inch in diameter (turbine meters) are accuracy tested and repaired and/or replaced as needed 3 times a year.

    - Wholesale meters are tested for accuracy and repaired and/or replaced as needed 3 times a year.

In a system as large and complex as MDWASD's, with 5,774 miles of water mains and numerous water treatment plants, booster stations, and storage structures, obtaining accurate and precise data for accounting all the water being produced at the treatment plants requires considerable effort. While the water loss audits for the current year are an improvement over the previous year, it has been recommended that MDWASD further enhance its procedures to better measure and validate its supply and customer demand information to improve its calculation of NRW and implement procedures to reduce the water losses.

3.3. IWA/AWWA Water Loss Audits Results

The water audit computational approach can be summarized into two steps: (1) subtract authorized metered and unmetered consumption from the water supplied to estimate all water losses and (2) subtract apparent losses, such as unauthorized consumption, customer metering inaccuracies, and systematic data handling errors, from the total water losses to estimate real water losses.

The results of the water loss audits are presented for CY 2011 in Appendix B. A summary of selected key input parameters and output results are presented in Table 3-5. The CY 2011 input parameters and results are compared against the past four years (2007 through 2010) results and are presented in Table 3-5 and Figure 3-1.

The total retail water supplied (finished water supplied to retail customers) in 2011 decreased about 5 percent compared to the total retail water supplied in 2009 and 2010. The year-over-year real losses appear to have increased somewhat over time from 2007 through 2010. However, the losses have decreased in 2011, which shows progress that MDWASD has made in reducing the NRW. Retail real water losses have increased from 18.3 percent (of the total retail water supplied) in 2007 to 23.4 percent in 2010 and have reduced to 22.3 percent in 2011. The non-revenue water losses have increased from 27.9 percent in 2007 to 32.8 percent in 2010 and have reduced to 30.2 percent in 2011. Though the reduction in water losses from 2010 to 2011 is not very substantial, it still shows an improvement and progress made by MDWASD in implementing the water loss reduction activities.

Table 3-5: IWA/AWWA Water Audit Key Input Parameters and Output Results

Retail Parameters	2011	2010	2009	2008	2007
Water Supplied (MG/Y)	90,626	94,552	94,950	91,515	92,240
Authorized consumption (MG/Y)	63,424	63,875	66,181	65,274	67,062
Apparent losses (MG/Y)	7,036	8,502	8,271	7,623	8,307
Real losses (MG/Y)	20,165	22,144	20,498	18,618	16,872
Water losses (apparent plus real)	27,202	30,647	28,769	26,241	25,179
Non-revenue water (MG/Y)	27,388	30,971	29,007	26,513	25,747
Performance indicators	2011	**2010**	**2009**	**2008**	**2007**
Infrastructure Leakage Index (ILI)	8.13	9.2	10.8	9.8	8.9
Real water loss percentage	22.3%	23.4%	21.6%	20.3%	18.3%
Non-revenue water percentage	30.2%	32.8%	30.6%	29.0%	27.9%

The reduction of water losses in 2011 can be attributed to the improved and effective leak detection program that MDWASD has currently in place. More details on the leak detection program are provided in Section 2 of this report. The large diameter transmission mains inspection, condition assessment, and resulting replacement program that was initiated by MDWASD in 2010 and was underway during 2011 has impacted the reduction of water losses in 2011.

Between 2007 and 2010, the MDWASD's water system ILI has varied between 8.9 and 10.8. The ILI for 2011, 8.1, is an improvement over the previous years. Part of the reason for the decrease in ILI in 2011 is due to an increase in overall system pressure with the availability of more refined pressure data, which allowed for a more accurate average pressure to be calculated, coupled with other improvements made by MDWASD. ILI is a function of several factors, including distribution system pressure and real losses.

In 2008, increases in the ILI were thought to be due to two large (48-inch) main breaks that occurred in the final quarter of that year. MDWASD staff report that major, ground-surfacing leaks are relatively rare, so the occurrence of these leaks caused a disproportionate amount of real water loss, which increased the ILI for 2008. In 2009, the average system pressure used for the water audit was based on data that had been collected previously in 2008. The actual average system pressure may have been higher, which would cause the ILI to be overestimated for that year. The year 2010 had been another challenging year from an infrastructure perspective, with additional failures of large diameter water transmission main occurring. The failure of the large diameter mains resulted in a significant quantity of potable water loss in 2010. A year-over-year decrease in ILI, coupled with decrease in water losses in 2011 is an improvement compared to the results from the past four years (2007 through 2010). However, MDWASD has to further enhance and make considerable efforts in the future to achieve its target ILI of below 3.

Figure 3-1: IWA/AWWA Water Audit Results

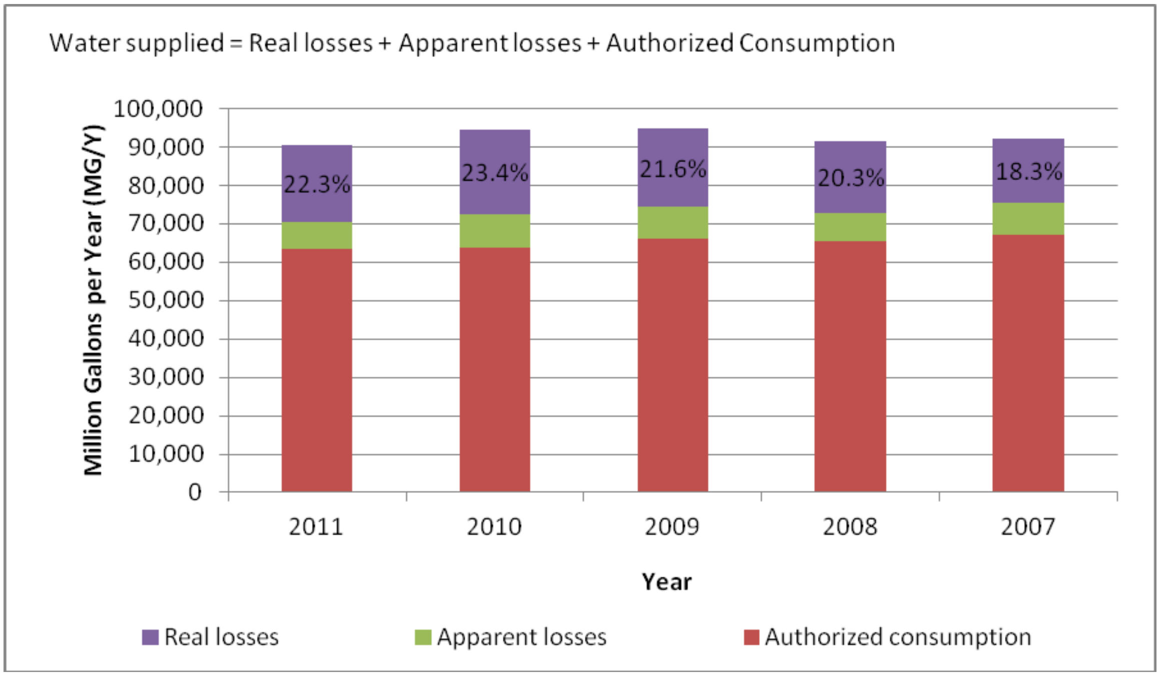


Figure 3-1 indicates that the year 2011 is the first year that demonstrates some improvement in reduction of distribution system water losses. MDWASD has made considerable progress initiating the implementation of recommendations presented in the 2007 Water Loss Reduction

Plan and has documented the subsequent annual audit results. Current strategies that were implemented and/or underway to reduce water losses are described in Section 2 of this report.

The AWWA free audit software Version 4.2 (that has been used since 2009) contains a data validation component and a quantified scoring method to classify audit data and assess the reliability of the audit results, which was not available in the original IWA/AWWA method and audit software. The current IWA/AWWA water audit provides definitions for each input data source and recommendations for improving the score. The data validation score for the MDWASD audits has been around 73 to 75 since 2009. It is recommended that MDWASD focus on data collection improvements in order to increase the reliability of the water audit results. The following is a list of items that require further enhancements for future water audits.

- A potential factor affecting the ILI's representation of actual system conditions is that the inaccuracies of the plant finished water and wholesale meters have not yet been fully quantified, although the testing and replacement program is underway. Quantification of, and accounting for, inaccuracies in supply and wholesale meters is critical to obtaining a meaningful ILI. MDWASD has quantified the inaccuracies of the Alexander Orr WTP raw water and finished water supply meters. MDWASD is recommended to also conduct accuracy testing for the Hialeah/Preston supply meters as wells as the wholesale meters and commercial meters, which will serve in the future to improve the accuracy of this "top-down" water loss audit.

- The IWA/AWWA water audits for the previous years accounted for potential unmetered connections to MDWASD's wholesale users as an apparent water loss. Due to insufficient data and a lot of uncertainty, the 2011 water audits did not take into account any such unmetered connections. However, it is recommended that MDWASD implement steps to estimate and reduce water losses through any such unmetered connections.

- Average retail unit costs and average unit cost of water production were estimated in a manner consistent with that described in the 2007 Water Loss Reduction Plan report, except that costs were estimated on a fiscal year basis and not a calendar year basis. The calculation of these costs based on fiscal year data greatly simplified the analysis, and had negligible effect on the water audits. However, it is recommended that MDWASD provide financial data based on calendar year, in order to further refine the preparation of future water audits.

- The water supplied by MDWASD to four fire departments is not currently accounted for in the water audits and therefore is unintentionally misrepresented as a water loss. In order to better account for this unbilled unmetered consumption, it is recommended that MDWASD develop procedures to reasonably estimate fire departments water use associated with routine activities, such as training, and eventful activities such as fire fighting.

4. Water Treatment Plant Audits

This section describes the annual Water Treatment Plant (WTP) Audits that were performed to meet the requirements of the Limiting Condition 49 of the MDWASD's Water Use Permit (WUP) by comparing metered raw water well flows, metered raw water influent, and finished water effluent at the MDWASD's three main water treatment plants.

4.1. Introduction

The majority of MDWASD's service area is supplied by three water treatment plants: (1) Alexander Orr, Jr. (Orr) WTP, (2) John E. Preston (Preston) WTP, and (3) Hialeah WTP.

All three WTPs treat raw water from Biscayne aquifer wellfields. Table 4-1 presents the list of wellfields that supply the three WTPs. The raw water transmission mains from the wellfields that supply Hialeah and Preston WTPs are interconnected such that any of the wellfields can supply either or both WTPs. Wellfields supplying the Hialeah/Preston plants are not interconnected with those that supply the Orr plant. Raw water flows are metered individually by well meters at the wellfield and metered in aggregate by inflow meters at each water treatment plant.

Table 4-1: Biscayne Aquifer Wellfields that Supply MDWASD's Major WTPs

Well Field	Number of Raw Water Wells
Hialeah/Preston WTPs	
Hialeah Wellfield	3
John E. Preston Wellfield	7
Miami Springs Wellfield	20
Medley Wellfield	4
Northwest Wellfield	15
Hialeah/Preston WTPS Wells	**49**
Orr WTP	
Alexander Orr Wellfield	10
Snapper Creek Wellfield	4
Southwest Wellfield	17
West Wellfield	3
Orr WTP Wells	**34**
Total Number of Wells	**83**

Source: MDWASD staff

In addition to the wellfields listed in Table 4-1, MDWASD also draws water from five wellfields (with a total number of 12 raw water wells) that supply the South Dade water treatment facilities (South Dade system). The raw water flow that was treated by the South Dade system in 2011 accounted for approximately 3 percent of the MDWASD's total raw water supply. It should be noted that the WTP audits for the South Dade system are not part of this report.

The MDWASD also has Aquifer Storage and Recovery (ASR) and Floridan blending capabilities, which are not currently being used at any of the WTPs. However, the metered readings at the individual wells indicate that a small quantity (approximately 23,000 gallons per month) of Floridan raw water was withdrawn from the Southwest ASR Wellfield during the months of April, May, and June of 2011. This flow was indicated to be sent to the Alexander Orr WTP.

MDWASD's three major WTPs use an enhanced lime softening treatment process in which water is treated with lime (to remove hardness) and activated silica (a flocculant aid). At the Hialeah/Preston WTPs, ferric sulfate is also added to enhance the removal of color and natural organic matter. The Hialeah/Preston WTPs are interconnected prior to the high service distribution pumping system and essentially function as a single plant. Waste solids from the softening process are either recycled through a recalcination process that converts the calcium carbonate solids back to lime or disposed of in sludge lagoons. Prior to disposal, solids are thickened/dewatered, and the water recovered from the thickening process is returned to the head of the plant. Remaining moisture in the solids prior to disposal or recycling represents the net water loss in the solids handling process.

Typically, the "real" water loss in a conventional treatment process is approximately 3 to 5 percent of raw water supplied. As mentioned above, solids produced by MDWASD plants are either recycled or pumped into a lagoon. Prior to recalcination, some of the water is extracted from the solids via centrifugation and returned to the treatment process. Water vaporized during the heating of the solids during recalcination is not recovered. Additionally, solids that are not recalcinated are pumped as a slurry solution (2 to 4 percent solids) to large lagoons, where excess water either percolates back into the Biscayne aquifer or evaporates. Small amounts of water are also used (lost) for monitoring plant performance. Water may also be lost via undetected leaks in water treatment plant structures and piping.

In addition to real losses, apparent water loss may also occur as a result of errors in the individual well meters, raw water supply Venturi meters, and finished water effluent meter readings. Metered raw water flows and finished water flows for the plants are analyzed in the following sub-sections to quantify the overall water losses at the Orr and Hialeah/Preston WTPs.

Although large quantities of water are used in the process for backwashing filters, feeding chemicals, etc., the great majority of this water is recycled back into the treatment process. Since all large process recycle streams occur internal to the plant – that is, downstream of the raw water influent meters and upstream of the finished water effluent meters – recycling these flows does not result in any amount of water being counted twice by plant meters.

4.2. Raw Water Flows Metered at Wells vs. WTP Venturi Meters

Tables 4-2 and 4-3 compare (a) the raw water flows metered at the wellfields and (b) the raw water influent flow metered at the WTPs. Individual flow meters on MDWASD's raw water wells were installed in 2008 and, since then, MDWASD has reported monthly raw water well flows based on data generated by these meters. In the tables, positive values indicate net decreases (quantity loss) in water flow, while negative values indicate net increases (quantity gains). This convention was selected because water loss is expected to occur, rather than "apparent" water gain, in a pressurized pipeline. Negative losses in Tables 4-2 and 4-3 indicate "apparent" water gains that may be due to raw water well meter under-registration and/or WTP raw water Venturi meter over-registration.

Table 4-2: Hialeah/Preston WTP Raw Water Flows from Wells vs. WTPs Venturi Meters

Month	Sum of Individual Well Flows (MG)	Raw Water Plant Venturi Flows (MG)	Volume Difference (MG)	Percent Difference (%)
January 2011	3,600	4,218	-618	-17%
February 2011	3,444	3,891	-446	-13%
March 2011	3,879	4,460	-581	-15%
April 2011	3,755	4,345	-591	-16%
May 2011	3,774	4,403	-630	-17%
June 2011	3,929	4,579	-650	-17%
July 2011	4,018	4,744	-726	-18%
August 2011	3,645	4,196	-552	-15%
September 2011	3,549	4,051	-502	-14%
October 2011	3,631	4,138	-506	-14%
November 2011	3,690	4,242	-552	-15%
December 2011	3,770	4,329	-558	-15%
Average	3,724	4,300	-576	-15%

Source: MDWASD monthly reports for CY 2011

In 2011, the combined sum of the raw water well meter readings were on average 15 percent less than the raw water influent meter readings at the Hialeah/Preston WTPs. This has stayed the same when compared to the results that were reported annually since 2008. That is, more water appears to have entered the plant than was pumped by the wells, which is unlikely to have actually occurred. In reality, it is far more likely that this represents a meter accuracy issue rather than a physical gain of water between the wells and the plants. Because both the individual well flow meters and the plant Venturi meters have some inherent error, differences in the summed wellfield total and the raw water Venturi meters would be expected; however, the magnitude of the difference observed indicates there may be arrangement/accuracy issues that need to be addressed. MDWASD plans to investigate and, where possible, improve the calibration, selection, and/or configuration of the well flow meters. Due to large number of these meters (49 meters at the Hialeah/Preston wellfields), the testing and calibration process is very time and labor intensive.

Also, it was indicated that there is a raw water booster pump station at the Preston WTP whose flow is not accounted for at the Venturi meters. It is recommended that MDWASD take actions to remedy this, which will allow for more accurate estimates of the raw and finished water losses to be estimated for subsequent years.

Table 4-3: Orr WTP Raw Water Flows from Wells vs. WTP Venturi Meters

Month	Sum of Individual Well Flows (MG)	Raw Water Plant Venturi Flows (MG)	*Raw Water Plant Venturi Flows – Adjusted (MG)	Volume Difference (MG)	Percent Difference (%)
January 2011	4,604	4,682	4,533	72	2%
February 2011	4,257	4,383	4,243	15	0%
March 2011	4,883	4,953	4,794	89	2%
April 2011	4,759	4,812	4,658	101	2%
May 2011	4,848	4,913	4,755	93	2%
June 2011	4,483	4,562	4,416	67	1%
July 2011	4,289	4,296	4,158	131	3%
August 2011	4,917	5,191	5,025	-108	-2%
September 2011	4,693	4,741	4,589	104	2%
October 2011	4,833	4,845	4,690	143	3%
November 2011	4,385	4,534	4,389	-4	0%
December 2011	4,620	4,674	4,524	96	2%
Average	4,631	4,715	4,565	67	1%

Source: MDWASD monthly reports for CY 2011

**Includes known raw water Venturi over-registration of 3.2 percent*

In 2011, the water losses computed from the differences in raw water well meter readings and the raw water influent meter readings at the Alexander Orr WTP averaged about 1 percent. This is an improvement over results reported annually since 2008 (2008 – approximately 11 percent gain, 2009 – approximately 22 percent gain, and 2010 – approximately 11 percent gain). It was reported in 2009 that the raw water meters at the Orr WTP over-register by 3.2 percent, on average. The water losses presented in Table 4-3 were estimated taking into account the known 3.2 percent raw water meter inaccuracy.

It was indicated by MDWASD staff that the well meters at the Orr WTP wellfields (total of 34 meters) were replaced in 2011 with new ultrasonic flow meters. The improvement in the reduction of apparent water losses from well meters compared to the raw water influent meters at the WTP can be attributed to these meter replacements.

According to AWWA Manual M33, a typical range of error for an ultrasonic-type flow meter is ±2.5 percent. The results presented in Table 4-3 for 2011 show that the water losses are within the acceptable range and, therefore, the new well meters appear to be performing well and are relatively precise.

4.3. WTP Metered Inflows vs. Outflows

Hialeah/Preston and Alexander Orr WTPs influent and effluent flows are Venturi metered. Tables 4-4 and 4-5 compare raw water and finished water flows at the Hialeah/Preston and Alexander Orr WTPs, respectively.

Table 4-4: Hialeah/Preston WTPs Raw Water and Finished Water Flows

Month	Raw Water Flows (MG)	Finished Water Flows (MG)	Volume Difference (MG)	Percent Difference (%)
January 2011	4,218	4,094	124	3%
February 2011	3,891	3,782	108	3%
March 2011	4,460	4,337	124	3%
April 2011	4,345	4,233	112	3%
May 2011	4,403	4,279	124	3%
June 2011	4,579	4,460	120	3%
July 2011	4,744	4,620	124	3%
August 2011	4,196	4,072	124	3%
September 2011	4,051	3,931	120	3%
October 2011	4,138	4,014	124	3%
November 2011	4,242	4,122	120	3%
December 2011	4,329	4,205	124	3%
Average	4,300	4,179	121	3%

Source: MDWASD monthly reports for CY 2011

The water losses at the Hialeah/Preston plant averaged 3 percent in 2011, which are within the range of treatment losses expected at conventional treatment plants. This is an improvement over the previous year's estimates (approximately 6 percent water losses reported in 2009 and approximately 8 percent water losses reported in 2010). Although comparative accuracy testing has not been completed on these meters, the fact that the difference in inflow and outflow quantities averaged consistently low in 2011 is indicative that the meters have been calibrated well with minimum errors.

Raw water flow through a booster pump station installed in 2004 at the Preston WTP is not currently accounted for at the raw water Venturi meters at the Hialeah/Preston WTPs. It is recommended that MDWASD take actions to remedy this, which will allow for more accurate estimates of the raw and finished water losses to be estimated for subsequent years.

Also, raw water influent meters (3 at the Preston WTP and 2 at the Hialeah WTP) and finished water effluent meters (2 at the Preston WTP and 5 at the Hialeah WTP) at the Hialeah/Preston WTPs are not currently testable, and most have constrained meter settings for setting up test taps. It is recommended that MDWASD consider alternative strategies that can be feasibly developed and implemented for meter accuracy testing.

Table 4-5: Orr WTP Raw Water and Finished Water Flows

Month	Raw Water Flows (MG)	*Raw Water Flows – Adjusted (MG)	Finished Water Flows (MG)	*Finished Water Flows – Adjusted (MG)	Volume Difference (MG)	Percent Difference (%)
January 2011	4,682	4,533	5,189	5,314	-781	-17%
February 2011	4,383	4,243	4,689	4,802	-559	-13%
March 2011	4,953	4,794	5,165	5,289	-495	-10%
April 2011	4,812	4,658	5,083	5,205	-547	-12%
May 2011	4,913	4,755	5,223	5,348	-593	-12%
June 2011	4,562	4,416	4,800	4,915	-499	-11%
July 2011	4,296	4,158	4,601	4,711	-553	-13%
August 2011	5,191	5,025	5,222	5,347	-323	-6%
September 2011	4,741	4,589	5,050	5,171	-582	-13%
October 2011	4,845	4,690	5,217	5,342	-652	-14%
November 2011	4,534	4,389	4,896	5,014	-624	-14%
December 2011	4,674	4,524	4,987	5,107	-582	-13%
Average	4,715	4,565	5,010	5,130	-566	-12%

Source: MDWASD monthly reports for CY 2011

**Includes known raw water Venturi over-registration of 3.2 percent and finished water under registration of 2.4 percent*

Results presented in Table 4-5 indicate that the raw water influent flow was on an average 12 percent less than the finished water outflow at the Orr WTP. That is, water was gained in the treatment process, which is unlikely to have actually occurred and represents a meter accuracy issue. The results reported for the previous years indicate an average of 5 percent water losses at the Orr WTP. Replacement of the raw water meters (four total) and finished water meters (five total) is underway at the Orr WTP, which will help in achieving accuracy of water loss measurements at this facility.

4.4. Conclusions and Recommendations

In general, the raw water discrepancies between the wellfield flow meters and the plant flow meters have been reduced at the Orr plant with the replacement of well meters. At the Hialeah/Preston plant, the losses have stayed the same compared to the annual updates since 2008. On the other hand, the apparent water losses at the Hialeah/Preston WTPs have been reduced and those at the Orr WTP have increased substantially.

The following presents a summary of results and findings from the WTP audits that were performed in 2011 for MDWASD’s major WTPs. Recommendations for each facility, which could enhance the accuracy of water loss measurements at these facilities, are also listed below.

4.4.1. Hialeah/Preston WTPs

Since 2008 (through 2011), the combined sum of the raw water well meter readings were on average 15 percent less than the raw water influent meter readings at the Hialeah/Preston WTPs, which represents a meter accuracy issue rather than a physical gain of water between the wells and the plants. The water losses at the Hialeah/Preston plant averaged 3 percent in 2011, which is an improvement over the previous year results and is within the range of treatment losses expected at conventional treatment plants.

These results indicate that the raw water and finished water meters at the Hialeah/Preston WTPs might be performing relatively well, but the raw water well meters have meter accuracy issues that need to be fixed. The following are the proposed recommendations to enhance the accuracy of water loss measurements and reduce apparent losses at Hialeah/Preston WTPs:

- Identify and remedy the cause of the apparent gain of water from raw water well meters to the raw water influent meters at the WTPs.

- Take actions to meter the flow from the raw water booster pump station at the Preston WTP, which will allow for more accurate estimates of the raw and finished water losses to be estimated for subsequent years.

- Consider alternative strategies that can be feasibly developed and implemented to avoid major hurdles to test the accuracy of the Venturi meters at the Hialeah/Preston WTPs.

4.4.2. Orr WTP

The water losses resulting from differences in raw water well meter readings and the raw water influent meter readings at the Alexander Orr WTP averaged about 1 percent in 2011. This is an improvement when compared to the previous year results and can be attributed to the meter replacements (34 total) that were performed in 2011 at the raw water wells. The raw water influent flow was on average 12 percent less than the finished water outflow at the Orr WTP. This is an increase in apparent losses at the Orr WTP compared to the previous year results since 2008.

These results indicate that the raw water well meters at the Orr WTP are relatively precise, but the raw water and finished water meters at the Orr WTP have meter accuracy issues that need to be fixed. The following is recommended to enhance the accuracy of water loss measurements and reduce apparent losses at the Orr WTP:

- Complete the replacement of the raw water meters and finished water meters currently underway at the Orr WTP, which will help in achieving accuracy of water loss measurements at this facility.

5. Water Loss Reduction Activities Status and Action Items

MDWASD has made progress in initiating the implementation of the recommendations of the 2007 Water Loss Reduction Plan. Currently, MDWASD is focused on better quantifying the nature and extent of water losses, which will allow it to strategically target and reduce water losses in the future. Current and additional strategies of MDWASD to reduce water losses are described in this Section.

Table 5-1 lists the action items to be implemented or developed under Exhibits 17A and 17B of the revised WUP, as listed in Tables 1-1 and 1-2, along with additional activities undertaken by MDWASD. The table describes the current status and provides recommended follow-up activities for each of the action items.

Table 5-1: Status of Water Loss Reduction Activities (Based on Exhibits 17A and 17B of WUP)

Line Item	Activity No.	Action Item	Status	Recommended Follow-Up Activities
1	5.3.1	*System Design*	Completed	None
2	5.3.2.3	*Asset Maintenance or Replacement* MDWASD initiated efforts to evaluate and improve the distribution pipe replacements.	In 2010, MDWASD performed an 'Economic Analyses of Leak Detection Program and Pipe Replacement' study, which evaluated historical trends to establish an adaptive strategy for pipe replacement and leak detection programs based on statistical analysis of leak incidences, investments, and economic levels of return. The study proposed a modified approach to align system betterment investments with economic impact assessment of leak incidences. MDWASD is currently updating distribution system data base with pipe age and pipe material to better correlate pipe breaks with pipe rehabilitation/replacement efforts. In 2010, MDWASD initiated the "Condition Assessment of Prestressed Concrete Cylinder Pipe (PCCP)" program which surveyed the major water transmission pipelines. As a result of the assessment, MDWASD developed a rehabilitation program using Carbon Fiber Reinforced Plastic (CFRP) system and over 40 miles of PCCP were inspected in 2011. As part of the future rehabilitation program, MDWASD will inspect 15 miles of PCCP pipe per year and all 36-inch diameter piping will be inspected over a 3-year period.	· Implement the modified approach for leak detection and pipe replacement as recommended by the study. · While collecting leak detection data, record the information that integrates the interconnectivity of the system and the relation to other sets of data, such as underground pipe material, size, age, and environment (i.e. soil type, soil corrosivity, etc.) that can help document the basis for pipe failure/causes of leak. · Continue the PCCP rehabilitation program, as recommended in the assessment.
3	5.3.2.4	*Reduce Maintenance Response times* MDWASD initiated efforts to reduce the time it takes for its maintenance crews to respond to leaks and to improve the speed and quality of its repairs.	MDWASD has increased the sensitivity of its leak detection program by reducing the distance between noise loggers and reducing the length of main surveyed at one time by leak detection crews, thereby reducing leak duration by reducing the time between leak initiation and detection. MDWASD is also in the process of incorporating leak detection data into the Enterprise Asset Management System (EAMS) to keep track of leak response time and inventory repairs (i.e. new and repatches).	· Perform a sample leak program, similar to that conducted in the Fall of 2008, every 2 years as a way to gauge the overall field effectiveness of the in-house program and provide oversight.
4	5.3.2.5	*Active Leakage Control and Sounding* MDWASD initiated an active leakage control and sounding program, including both unmanned (noise logger) and manned leak	MDWASD has increased the sensitivity of its leak detection program by reducing the distance between noise loggers and reducing the length of main surveyed at one time by leak detection crews, thereby reducing leak duration by reducing the time between leak initiation and detection. In 2010, MDWASD performed an 'Economic Analyses of Leak Detection Program and Pipe Replacement' study, which evaluated historical trends to establish an	· Implement the modified approach for leak detection and pipe replacement as recommended by the study. · Update the distribution system data base with pipe age and pipe material to better correlate pipe breaks with pipe rehabilitation/replacement efforts · While collecting leak detection data, record the

Line Item	Activity No.	Action Item	Status	Recommended Follow-Up Activities
		surveys.	adaptive strategy for pipe replacement and leak detection programs based on statistical analysis of leak incidences, investments, and economic levels of return. The study proposed a modified approach to align system betterment investments with economic impact assessment of leak incidences. MDWASD is also in the process of incorporating leak detection data into the Enterprise Asset Management System (EAMS) to keep track of leak response time and inventory repairs (i.e. new and repatches).	information that integrates the interconnectivity of the system and the relation to other sets of data, such as underground pipe material, size, age, and environment (i.e. soil type, soil corrosivity, etc.) that can help document the basis for pipe failure/causes of leak.
5	5.3.2.7	*Pressure Managment* As part of this, MDWASD plans to complete a Zone Management Pilot.	MDWASD is in the process of developing a pilot study for Pressure and Zone Management that will assess a strategy for timely reducing system-wide real water losses (and attendant non-revenue water) without compromising level of service.	· Develop pilot study.
6	5.3.2.8	*Speed and Quality of Repairs* MDWASD initiated efforts to improve the speed and quality of its repairs.	MDWASD has increased the sensitivity of its leak detection program by reducing the distance between noise loggers and reducing the length of main surveyed at one time by leak detection crews, thereby reducing leak duration by reducing the time between leak initiation and detection. In 2010, MDWASD performed an 'Economic Analyses of Leak Detection Program and Pipe Replacement' study, which evaluated historical trends to establish an adaptive strategy for pipe replacement and leak detection programs based on statistical analysis of leak incidences, investments, and economic levels of return. The study proposed a modified approach to align system betterment investments with economic impact assessment of leak incidences. MDWASD is also in the process of incorporating leak detection data into the Enterprise Asset Management System (EAMS) to keep track of leak response time and inventory repairs (i.e. new and repatches).	· Implement the modified approach for leak detection and pipe replacement as recommended by the study. · Update the distribution system data base with pipe age and pipe material to better correlate pipe breaks with pipe rehabilitation/replacement efforts. · While collecting leak detection data, record the information that integrates the interconnectivity of the system and the relation to other sets of data, such as underground pipe material, size, age, and environment (i.e. soil type, soil corrosivity, etc.) that can help document the basis for pipe failure/causes of leak.
7	-	*Perform Venturi Comparative Tests - WTPs* MDWASD is currently performing comparative accuracy testing on the combined raw and finished water meters at its water treatment plants.	Testing was conducted at the Alexander Orr Plant for four raw water Venturi Meters and five finished water meters. Replacment of Alexander Orr Venturi meters is currently underway and is anticipated to be completed by 2012. Testing for the raw and finished Venturi water meters at the Preston and Hialeah plants cannot be performed until test taps are installed. Unable to install test taps needed to validate the level of metering accuracy at the Preston/Hialeah plants due to configuration issues.	· Further assess feasibility of achieving testing goals and devise an alternate approach. · Identify any capital projects that may be required to support meter testing.
8	-	*Perform Venturi Comparative Tests - Wholesale Customers* MDWASD is currently performing comparative accuracy testing on its	Venturi Meter Sites: In 2010, steps were taken to connect these meters to SCADA. However, the meter readings are unavaialable. Test tap installations that are required for accuracy testing are pending. Turbine Meter Sites: In 2010, these meters were all connected to the AMR system.	· Plan Capital Improvement Program required for testing inaccessible meters.

Line Item	Activity No.	Action Item	Status	Recommended Follow-Up Activities
		wholesale customer venturi, turbine, and positive displacement meters.	Evaluation of other wholesale meters is pending upon installation of additional test taps.	
9	-	*Pilot Fixed Network AMR* MDWASD is currently expanding the AMR network.	MDWASD performed an Automated Meter Reading (AMR) Residential Pilot Program with fixed network Advanced Metering Infrastructure (AMI) systems from two manufacturers: Itron, Inc. and Sensus Metering Systems, Inc. As part of the pilot, 1,000 AMR meters were installed in MDWASD's service area. In 2010, MDWASD initiated the expansion of the AMI network with the installation of additional AMI meters from Sensus Metering Systems, Inc. To date, a total of 820 AMI meters in the MDWASD service area and 4,000+ AMRs in the Miami Springs service area have been installed. Currently, MDWASD is working on a joint AMI project with the Parks department. The AMR/AMI pilot program is being extended into Miami Springs service area and will add 4,300 meters to the AMI system.	· Continue to expand AMR/AMI network in the MDWASD service area.
10	-	*Enhance GIS Database* MDWASD is currently enhancing its GIS database.	MDWASD is currently enhancing its GIS database to include more information on its distribution system features (pipe lengths, diameters, materials, age in service, etc.). MDWASD is close to completing this action item.	· Plan integrated use of expanded capabilities in asset management program.
11	6.3.1	*Reducing Unmetered Supplies* MDWASD initiated efforts to reduce unmetered water supplies.	Fire fighting and main flushing are the largest unmetered uses in MDWASD's system. Although not metered, main flushing volumes are estimated using industry-accepted protocol and are consistently recorded. Usage by fire departments is currently neither estimated nor recorded. In 2010, Fire Departments that receive water from MDWASD were identified and contacted to request their cooperation in developing a methodology to better account for their water usage.	· Conduct a meeting with the identified Fire Departments to evaluate their water usage. · Based on the feedback from the Fire Departments, develop a methodology for appropriately accounting for Fire Department water use.
14	6.3.2	*Improved Meter Accuracy* *MDWASD is conducting field accuracy testing of commercial meters to begin improving meter accuracy.*	Turbine Meter Sites: Testing of 9 commercial customer sites where two different sized meters were used in a "compound" setting has been completed in the past and results are available in a report. Some commercial meter sites have proved to be challenging to test, not because of the sites, but because of circumstances such as Jackson Hospital's inability to shut down an entire line for testing purposes. In 2010, a dedicated testing site was installed to test 4-inch meters and compare them to the 4-inch by 2-inch compound meters. In 2011, two new technologies (ultra sound and electromagnetic meters) are being tested. Commercial meter sizing criteria was reviewed in 2008, and it has been recommended that MDWASD move to a more standardized approach consistent with current AWWA recommended practices.	· Perform recurring testing of commercial meters to cover entire inventory over time. Determine testing frequency by meter configuration based on economical and statistical analyses of commercial meter samples. · Install test taps at locations that have been evaluated and inspected where displacement meters and turbine meters were being used in a compound setting. · Install new type electromagnetic meters for better accuracy and less maintenance.

Line Item	Activity No.	Action Item	Status	Recommended Follow-Up Activities
			In 2010, meter sizing criteria consistent with AWWA standards was developed and is available in a report. Currently, MDWASD is investing on modern electromagnetic flow meters such as Eslter EvoQ4 and Sensus accuMAG. This type of meters provide extended accuracy ranges as the "Omni" meters, but have no moving parts and only require battery replacement every 5-10 years (depending on the meter size).	
15	6.3.3.2.1	*Compound Meter Usage Compared to Same Size Turbine Meters* MDWASD initiated efforts to compare compound meter usage to similarly-sized turbine meter settings.	MDWASD has obtained a few new style "Omni" meters from Sensus for evaluation that acts as compound meters. These meters were installed by MDWASD at various sites and passed the evaluation process with satisfactory results regarding measurement of ultra low flows with a full range of high flows. The “Omni” meters have now become standard for MDWASD.	· Document the initial evaluation of "Omni" meters. · Develop a data base with testing data results. · Continue replacing the obsolete turbine meters with "Omni" or other reliable meters currently under evaluation by MDWASD.
16	6.3.3.3	*Looking Forward (Setting Economic Meter Testing Goal)*	Completed	· None
17	6.3.4	*Improved Calibration of Wholesale Customer Meters* MDWASD is currently performing comparative accuracy testing on its wholesale customer venturi, turbine, and positive displacement meters.	Venturi Meter Sites: In 2010, steps were taken to connect these meters to SCADA. However, the meter readings ae unavailable. Test tap installations that are required for accuracy testing are pending. Turbine Meter Sites: In 2010, these meters were all connected to the AMR system. MDWASD performs twice a year the testing of the wholesale turbine meters.	· Plan Capital Improvement Program required for testing inaccessible meters.
18	6.3.5	*Wholesale Customer Unmetered Connection Analysis* MDWASD initiated unmetered wholesale customer connection survey and analysis.	In 2009, MDWASD found a wholesale meter by-pass that was open allowing unmetered water delivery to the wholesale customer. All by-pass meters have now been locked and evaluation of metering or connection to SCADA will be undertaken in 2011.	· Complete the evaluation of metering and connection to SCADA of the wholesale meters
19	-	*Determine economic optimum for residential meter replacement:* This item requires that MDWASD characterize residential water demand patterns and determine economic optimum for residential meter replacement.	"Meter Master" loggers have been deployed to characterize residential demand since October 2008 and have been rotated through a representative set of meters on a weekly basis. Residential demand data, along with age and meter testing data, will be used to establish an economic optimum for meter replacement. Data collection has been completed. Sensus SR model meter is an old meter design that comprises most of the MDWASD's meter inventory. In 2010, MDWASD investigated different meter models and is considering new meters such as Sensus “iPERL”. In 2011, MDWASD started the implementation of 4,000+ "iPERL" meters which have integral data logging.	· Continue logging data from new-model meters installed in the system to update the assessment of the economic optimum replacement. · Continue the replacement of residential meters with the new "iPERL" meters with integral data logging.

Appendix A

Revised Water Use Permit

FORM #0329
Rev. 07/05

SOUTH FLORIDA WATER MANAGEMENT DISTRICT
WATER USE PERMIT NO. RE-ISSUE 13-00017-W
NON-ASSIGNABLE

Date Issued: November 1, 2010 **Expiration Date:** November 3, 2030

Authorizing: THE CONTINUATION OF AN EXISTING USE OF GROUNDWATER FROM THE BISCAYNE AQUIFER AND UPPER FLORIDAN AQUIFER FOR PUBLIC WATER SUPPLY AND AQUIFER STORAGE AND RECOVERY USE WITH AN ANNUAL ALLOCATION OF 149106 MILLION GALLONS.

Located In: Miami-Dade County, S-/T53S/R39E (See attached for additional
S-/T53S/R40E Sections, Townships and Ranges)

Issued To: MIAMI-DADE WATER AND SEWER DEPARTMENT
(MIAMI-DADE CONSOLIDATED P W S)
ATTN: UTILITY DIRECTOR,3071 SW 38TH AVENUE
MIAMI, FL 33146

This is to notify you of the District's agency action concerning Permit Application No. 091228-14, dated December 28, 2009. This action is taken pursuant to the provisions of Chapter 373, Part II, Florida Statutes (F.S.), Rule 40E-1.603 and Chapter 40E-2, Florida Administrative Code (F.A.C.). Based on the information provided, District rules have been adhered to and a Water Use Permit is in effect for this project subject to:

1. Not receiving a filed request for an administrative hearing pursuant to Section 120.5 and Section 120.569, or request a judicial review pursuant Section 120.68, Florida Statutes.
2. The attached 52 Limiting Conditions.
3. The attached 37 exhibits.

Permittee agrees to hold and save the South Florida Water Management District and its successors harmless from any and all damages, claims or liabilities which may arise by reason of the construction, maintenance or use of activities authorized by this permit. Said application, including all plan and specifications attached thereto, is by reference made a part hereof.Upon written notice to permittee, this permit may be temporarily modified, or restricted under a Declaration of Water Shortage or a Declaration of Emergency due to Water Shortage in accordance with provisions of Chapter 373, Fla. Statutes, and applicable rules and regulations of the South Florida Water Management District. This Permit may be permanently or temporarily revoked, in whole or in part, for the violation of the conditions of the permit or for the violation of any provision of the Water Resources Act and regulations thereunder. This Permit does not convey to the permittee any property rights nor any privileges other than those specified herein, nor relieve the permittee from complying with any law, regulation, or requirement affecting the rights of other bodies or agencies.

Should you object to these conditions, please refer to the attached "Notice of Rights" which addresses the procedures to be followed if you desire a public hearing or other review of the proposed agency action. Should you wish to object to the proposed agency action or file a petition or request, please provide written objections, petitions, requests and/or waivers to:

Elizabeth Veguilla, Deputy Clerk, MSC2440
South Florida Water Management District
Post Office Box 24680
West Palm Beach, FL 33416-4680

Please contact this office if you have any questions concerning this matter. If we do not hear from you in accordance with the "Notice of Rights", we will assume that you concur with the District's action.

CERTIFICATION OF SERVICE

I HEREBY CERTIFY that the Staff Report, Conditions and Notice of Rights have been mailed to the Permittee (and the persons listed on the attached staff report distribution list) no later than 5:00 p.m. on this 2nd day of November, 2010, in accordance with Section 120.60(3), Florida Statutes, and a copy has been filed and acknowledged with the Deputy District Clerk.

ORIGINAL SIGNED BY
By **ELIZABETH VEGUILLA**
DEPUTY CLERK
SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Attachments
CERTIFIED MAIL# 70050390000598223083

LIMITING CONDITIONS

1. This permit shall expire on November 3, 2030.
2. Application for a permit modification may be made at any time.
3. Water use classification:

   Public water supply
   Aquifer storage and Recovery

4. Source classification is:

   Ground Water from:
   Biscayne Aquifer
   Upper Floridan Aquifer

   Reclaimed Water from:
   MDWASD South District WWTP
   MDWASD West District Water Reclamation Plant

5. Annual allocation shall not exceed 149106 MG.

   Maximum monthly allocation shall not exceed 13047 MG.

   The following limitations to the average annual withdrawals from specific sources are applicable through December 31, 2015:
   Biscayne aquifer: 125,458 MG
   Floridan aquifer: 4,855 MG
   The following limitations to the average annual withdrawals from specific sources are applicable from January 1, 2016 through December 31, 2020:
   Biscayne aquifer: 131,645 MG
   Floridan aquifer: 4,855 MG
   Reuse offset: 6,796 MG (South Miami Heights recharge)
   The following limitations to the average annual withdrawals from specific sources are applicable from January 1, 2021 through December 31, 2025:
   Biscayne aquifer: 137,010 MG
   Floridan aquifer: 4,855 MG
   Reuse offset: 12,753 MG (South Miami Heights & SWWF recharge)
   The following limitations to the average annual withdrawals from specific sources are applicable from January 1, 2026 through December 31, 2030:
   Biscayne aquifer: 141,824 MG
   Floridan aquifer: 7,282 MG
   Reuse offset: 17,630 MG (So. Miami Heights & SWWF recharge)
   The allocations above are further constrained by the wellfield operational plan described in Limiting Condition 27. The offset reuse allocations do not include the reuse projects outlined in Limiting Condition 39 that are in addition to the wellfield recharge projects.

6. Pursuant to Rule 40E-1.6105, F.A.C., Notification of Transfer of Interest in Real Property, within 30 days of any transfer of interest or control of the real property at which any permitted facility, system, consumptive use, or activity is located, the permittee must notify the District, in writing, of the transfer giving the name and address of the new owner or person in control and providing a copy of the instrument effectuating the transfer, as set forth in Rule 40E-1.6107, F.A.C.

Pursuant to Rule 40E-1.6107 (4), until transfer is approved by the District, the permittee shall be liable for compliance with the permit. The permittee transferring the permit shall remain liable for all actions that are required as well as all violations of the permit which occurred prior to the transfer of the permit.

Failure to comply with this or any other condition of this permit constitutes a violation and pursuant to Rule 40E-1.609, Suspension, Revocation and Modification of Permits, the District may suspend or revoke the permit.

This Permit is issued to:

Miami-Dade Water and Sewer Department
3071 Sw 38th Ave
Miami, FL 33146
Attn: Utility Director

7. Withdrawal Facilities:

Ground Water - Proposed:

13 - 17" X 1490' X 1400 GPM Wells Cased To 1080 Feet
1 - 24" X 50' X 2800 GPM Well Cased To 45 Feet
2 - 24" X 50' X 1042 GPM Wells Cased To 45 Feet
9 - 24" X 50' X 1400 GPM Wells Cased To 45 Feet

Ground Water - Existing:

6 - 20" X 100' X 4900 GPM Wells Cased To 40 Feet
2 - 24" X 70' X 6945 GPM Wells Cased To 35 Feet
4 - 40" X 100' X 10420 GPM Wells Cased To 57 Feet
1 - 42" X 68' X 10000 GPM Well Cased To 60 Feet
1 - 6" X 30' X 400 GPM Well Cased To 25 Feet
1 - 30" X 1210' X 3500 GPM Well Cased To 835 Feet
1 - 24" X 70' X 3470 GPM Well Cased To 35 Feet
10 - 48" X 80' X 10420 GPM Wells Cased To 46 Feet
1 - 42" X 68' X 8500 GPM Well Cased To 60 Feet
1 - 30" X 1300' X 3500 GPM Well Cased To 850 Feet
2 - 12" X 40' X 1600 GPM Wells Cased To 35 Feet
1 - 14" X 115' X 3800 GPM Well Cased To 80 Feet
1 - 18" X 55' X 500 GPM Well Cased To 42 Feet
2 - 24" X 100' X 7500 GPM Wells Cased To 50 Feet
1 - 42" X 107' X 7000 GPM Well Cased To 69 Feet
1 - 16" X 50' X 1600 GPM Well Cased To 40 Feet
1 - 30" X 1200' X 3500 GPM Well Cased To 760 Feet
4 - 24" X 104' X 6940 GPM Wells Cased To 54 Feet
1 - 30" X 115' X 4170 GPM Well Cased To 80 Feet
1 - 42" X 68' X 8500 GPM Well Cased To 54 Feet
1 - 17" X 1490' X 1400 GPM Well Cased To 1150 Feet
1 - 16" X 100' X 7500 GPM Well Cased To 40 Feet
1 - 30" X 1250' X 3500 GPM Well Cased To 845 Feet
1 - 12" X 35' X 1200 GPM Well Cased To 30 Feet
1 - 12" X 35' X 800 GPM Well Cased To 30 Feet
1 - 12" X 40' X 800 GPM Well Cased To 35 Feet
7 - 16" X 100' X 4170 GPM Wells Cased To 40 Feet
4 - 24" X 100' X 4900 GPM Wells Cased To 35 Feet
6 - 42" X 107' X 7000 GPM Wells Cased To 66 Feet

1 - 48" X 80' X 10416.67 GPM Well Cased To 46 Feet
20 - 14" X 115' X 2500 GPM Wells Cased To 80 Feet
1 - 18" X 55' X 1500 GPM Well Cased To 45 Feet
4 - 24" X 108' X 8300 GPM Wells Cased To 50 Feet
1 - 18" X 50' X 500 GPM Well Cased To 40 Feet
1 - 30" X 115' X 2500 GPM Well Cased To 80 Feet
1 - 30" X 1200' X 3500 GPM Well Cased To 765 Feet
3 - 48" X 88' X 7500 GPM Wells Cased To 33 Feet
1 - 18" X 66' X 1500 GPM Well Cased To 53 Feet
1 - 18" X 65' X 1500 GPM Well Cased To 50 Feet
1 - 42" X 68' X 10000 GPM Well Cased To 54 Feet

Reclaimed Water - Proposed:

1 - " x HP X 12000 GPM Pump
2 - " x HP X 10000 GPM Pumps

8. Permittee shall mitigate interference with existing legal uses that was caused in whole or in part by the permittee's withdrawals, consistent with the approved mitigation plan. As necessary to offset the interference, mitigation will include pumpage reduction, replacement of the impacted individual's equipment, relocation of wells, change in withdrawal source, or other means.

   Interference to an existing legal use is defined as an impact that occurs under hydrologic conditions equal to or less severe than a 1 in 10 year drought event that results in the:

   (1) Inability to withdraw water consistent with provisions of the permit, such as when remedial structural or operational actions not materially authorized by existing permits must be taken to address the interference; or

   (2) Change in the quality of water pursuant to primary State Drinking Water Standards to the extent that the water can no longer be used for its authorized purpose, or such change is imminent.

9. Permittee shall mitigate harm to existing off-site land uses caused by the permittee's withdrawals, as determined through reference to the conditions for permit issuance. When harm occurs, or is imminent, the District will require the permittee to modify withdrawal rates or mitigate the harm. Harm caused by withdrawals, as determined through reference to the conditions for permit issuance, includes:

   (1) Significant reduction in water levels on the property to the extent that the designed function of the water body and related surface water management improvements are damaged, not including aesthetic values. The designed function of a water body is identified in the original permit or other governmental authorization issued for the construction of the water body. In cases where a permit was not required, the designed function shall be determined based on the purpose for the original construction of the water body (e.g. fill for construction, mining, drainage canal, etc.)

   (2) Damage to agriculture, including damage resulting from reduction in soil moisture resulting from consumptive use; or

   (3) Land collapse or subsidence caused by reduction in water levels associated with consumptive use.

10. Permittee shall mitigate harm to the natural resources caused by the permittee's withdrawals, as determined through reference to the conditions for permit issuance. When harm occurs, or is imminent, the District will require the permittee to modify withdrawal rates or mitigate the harm. Harm, as determined through reference to the conditions for permit issuance includes:

    (1) Reduction in ground or surface water levels that results in harmful lateral movement of the fresh water/salt water interface,

(2) Reduction in water levels that harm the hydroperiod of wetlands,

(3) Significant reduction in water levels or hydroperiod in a naturally occurring water body such as a lake or pond,

(4) Harmful movement of contaminants in violation of state water quality standards, or

(5) Harm to the natural system including damage to habitat for rare or endangered species.

11. If any condition of the permit is violated, the permit shall be subject to review and possible modification, enforcement action, or revocation.

12. Authorized representatives of the District shall be permitted to enter, inspect, and observe the permitted system to determine compliance with special conditions.

13. The Permittee is advised that this permit does not relieve any person from the requirement to obtain all necessary federal, state, local and special district authorizations.

14. The permit does not convey any property right to the Permittee, nor any rights and privileges other than those specified in the Permit and Chapter 40E-2, Florida Administrative Code.

15. Permittee shall submit all data as required by the implementation schedule for each of the limiting conditions to: SFWMD, P.O. Box 24680, West Palm Beach, FL 33416-4680.

16. In the event of a declared water shortage, water withdrawal reductions will be ordered by the District in accordance with the Water Shortage Plan, Chapter 40E-21, F.A.C. The Permittee is advised that during a water shortage, pumpage reports shall be submitted as required by Chapter 40E-21, F.A.C.

17. Prior to the use of any proposed water withdrawal facility authorized under this permit, unless otherwise specified, the Permittee shall equip each facility with a District-approved operating water use accounting system and submit a report of calibration to the District, pursuant to Section 4.1, Basis of Review for Water Use Permit Applications.

    In addition, the Permittee shall submit a report of recalibration for the water use accounting system for each water withdrawal facility (existing and proposed) authorized under this permit every five years from each previous calibration, continuing at five-year increments.

18. Monthly withdrawals for each withdrawal facility shall be submitted to the District quarterly. The water accounting method and means of calibration shall be stated on each report.
    The permittee shall report injection/withdrawals from the ASR wells in the following manner:

    Biscayne Aquifer water injected
    Biscayne Aquifer water recovered
    Floridan Aquifer withdrawal

19. The Permittee shall provide annual status reports to the District that summarize the ASR cycle testing activities. The first report shall be submitted by:
    March 15, 2011

20. The Permittee shall notify the District within 30 days of any change in service area boundary. If the Permittee will not serve a new demand within the service area for which the annual allocation was calculated, the annual allocation may then be subject to modification and reduction.

21. The Permittee shall submit to the District an updated Well Description Table (Table A) within one month of completion of the proposed wells identifying the actual total and cased depths, pump manufacturer and model numbers, pump types, intake depths and type of meters.

22. Permittee shall secure a well construction permit prior to construction, repair, or abandonment of all wells, as described in Chapters 40E-3 and 40E-30, Florida Administrative Code.

23. Every ten years from the date of permit issuance, the permittee shall submit a water use compliance report for review and approval by District Staff, which addresses the following:

1. The results of a water conservation audit that documents the efficiency of water use on the project site using data produced from an onsite evaluation conducted. In the event that the audit indicates additional water conservation is appropriate or the per capita use rate authorized in the permit is exceeded, the permittee shall propose and implement specific actions to reduce the water use to acceptable levels within timeframes proposed by the permittee and approved by the District.

2. A comparison of the permitted allocation and the allocation that would apply to the project based on current District allocation rules and updated population and per capita use rates. In the event the permit allocation is greater than the allocation provided for under District rule, the permittee shall apply for a letter modification to reduce the allocation consistent with District rules and the updated population and per capita use rates to the extent they are considered by the District to be indicative of long term trends in the population and per capita use rates over the permit duration. In the event that the permit allocation is less than allowable under District rule, the permittee shall apply for a modification of the permit to increase the allocation if the permittee intends to utilize an additional allocation, or modify its operation to comply with the existing conditions of the permit.

3. Summary of the current and previous nine years progress reports for implementation of the Alternative Water Supply Plan and any modifications necessary to continue to meet the Plan requirements and conditions for issuance.

4. Information demonstrating that the conditions for issuance of the permit are being complied with, pursuant to Limiting Condition # 51 and Section 373.236, F.S.

5. Updates or amendments to the County's reuse plan.

24.

In order to promote use of alternative water supplies, pumpage from Floridan aquifer wells and from those Biscayne aquifer wells whose use is offset by reclaimed water will be conducted on a priority basis, referred to as a "first on, last off" priority. Changes to wellfield operations must be approved via modification of the approved Wellfield Operation Plan by District staff prior to implementation.

25.

The permittee shall operate surface water control structure known as the Mid-canal structure and bridge in accordance with the approved operational plan included in Exhibit 22. In addition, whenever this structure is opened for the purpose of raising water in the Wellfield Protection Canal down stream of the structure, the upstream structure that delivers water from the L-30 canal shall be opened in a manner to deliver equal volumes to those passed through the Mid-canal structure and bridge. The permittee shall submit operation and flow data logs regarding both structures to the District quarterly.

26.

The Permittee is authorized to exercise the emergency wells at the Medley Wellfield for a total of two hours per month as needed for bacterial clearance and pump maintenance. Operation of the emergency wells at the Medley Wellfield for more than this amount shall require prior approval from SFWMD. Pumpage data shall be collected and report in accordance with Limiting Condition 18.

27. Permittee shall implement the wellfield operating plan described in District staff report prepared in support of recommendation for permit issuance.
See Exhibit 10

28.

No more than 15 MGD shall be withdrawn from the West Biscayne aquifer Wellfield on any given day.

29.

No more than 25,550 MGY shall be withdrawn during any 12 month consecutive period from the combined Hialeah, Preston and Miami Springs Biscayne aquifer wellfields

30.

No more than 8,065 MGY shall be withdrawn during any 12 month consecutive period from the Snapper Creek Wellfield unless reclaimed water recharge is implemented in locations and amounts necessary to offset the impact of the increase to Everglades water bodies per limiting conditions 39 and 41.

31.

No more than 31,353 MGY shall be withdrawn during any 12 month consecutive period from the Southwest Biscayne aquifer Wellfield unless reclaimed water recharge is implemented in locations and amounts necessary to offset the impact of the increase to Everglades water bodies per limiting conditions 39 and 41.

32.

No more than 67,343 MGY shall be withdrawn during any 12 month consecutive period from the combined West, Southwest Snapper Creek and Alexander Orr Biscayne aquifer wellfields unless reclaimed water recharge is implemented in locations and amounts necessary to offset the impact of the increase to Everglades water bodies per limiting conditions 39 and 41.

33.

No more than 1,825 MGY shall be withdrawn during any 12 month consecutive period from the South Miami Heights Wellfield unless reclaimed water recharge is implemented in locations and amounts necessary to offset the impact of the increase to Everglades water bodies per limiting conditions 39 and 41.

34.

No more than 1,497 MGY shall be withdrawn during any 12 month consecutive period from the combined Everglades Labor Camp and Newton wellfields.

35.

No more than 1,745 MGY shall be withdrawn during any 12 month consecutive period from the combined Elevated Tank, Leisure City and Naranja wellfields.

36. The Permittee shall continue to submit monitoring data in accordance with the approved water level monitoring program for this project.
The existing monitoring program is described in Exhibits 30 and 32.

37. The Permittee shall continue to submit monitoring data in accordance with the approved saline water intrusion monitoring program for this project.
See exhibit 28C for a schedule of completion of the USGS project to update the salt front delineation and monitoring network.
The permittee shall submit annual Monitoring Program summary reports. The annual report will summarize the status of the project to update the salt front and install new monitor wells.

38.

Within six months, an executed large user water agreement with the City of Hialeah shall be submitted to the District. In the event that the final agreement is for volumes less than those used in the formulation of the allocations in this permit, the allocations shall be reduced through a letter modification.

39.

The permittee shall implement a minimum of 170 MGD of reuse projects as set forth in Projects 1-8 of Exhibit 30 on or before the deadlines provided therein. The exact volume of reclaimed water applied will depend on the treatement losses resulting from the process that are implemented. In the event any of these projects do not require or allow as much reuse as anticipated, the County shall identify and implement other reuse projects that will provide provide beneficial reuse of water by the deadlines set forth in Exhibit 30. Any changes to Exhibit 30 must be reviewed and approved by the District in consultation with the Department of Environmental Protection (DEP) in accordance with Parts

I & II of Chapter 373, Florida Statutes, and District rules governing consumptive uses of water in Chapter 40E-2, F.A.C., and DEP rules governing the treatment and use of reclaimed water in Chapter 62-610, F.A.C.

40.

The permittee will develop alternative water supplies in accordance with the schedules described in Exhibit 13.
The permittee will provide annual updates of the status of all alternative water supply projects (per the timeframes contained in Limiting Condition 50). The status report shall include work completed to date, expenditures and any anticipated changes in the timelines.

41.

In the event that a milestone specified in the alternative water supply schedule and plan contained in Exhibit 13 is going to be missed, the permittee shall notify the Executive Director of the District in writing explaining the nature of the delay, actions taken to bring the project back on schedule and an assessment of the impact the delay would have on the rates of withdrawals from the Everglades water bodies and associated canals as defined in SFWMD consumptive use permitting rules. The District will evaluate the situation and take actions as appropriate which could include: a.) granting an extension of time to complete the project (if the delay is minor and doesn't affect the Everglades Waterbodies or otherwise violates permit conditions), b.) take enforcement actions including consent orders and penalties, c.) modify allocations contained in this permit from the Biscayne aquifer including capping withdrawal rates until the alternative water supply project(s) are completed (in cases where the delay would result in violations of permit conditions) or d.) working with the Department of Community Affairs to limit increase demands for water until the alternative water supply project is completed.

42.

The Permittee shall provide the District with annual updates by March 15th each year describing the activities associated with the implementation of their approved reuse feasibility plan including the following information: (1) the status of distribution system construction, including location and capacity of a) existing reuse lines b) proposed reuse lines to be constructed in the next five years; (2) a summary of uncommitted supplies for the next five years; (3) the status of reuse plan implementation including status of pilot projects, plan design construction, volume of reuse available, volume of wastewater disposed of; and (4) the status/copies of any ordinances related to reuse (5) any proposed changes to the reuse plan set forth in Exhibit 30. The first annual update is due March 15, 2011.

43.

Reuse Project numbers 4, 6, and 7 in Exhibit 14 for wellfield recharge must be in place and operating prior to any additional withdrawals from the wellfield over the base condition water use as identified in Exhibit 10D.

44.

By November 15, 2012, the Permittee shall submit a report for District review and approval identifying the location, treatment, timing and volume for Reuse Projects 6 & 7 on Exhibit 14 which provide groundwater recharge for the Southwest Wellfield. The report shall demonstrate that the proposed recharge sites and operations shall at a minimum prevent increased withdrawals from the C-4, C-2 and eastward groundwater seepage from Everglades National Park over the base condition water use and is otherwise a beneficial reuse of water per Chapter 62-610, F.A.C.

45.

For Reuse Project number 5 of Exhibit 14 for rehydration of Biscayne Coastal Wetlands, the Permittee shall develop and complete a pilot testing program in consultation with the District, the Florida Department of Environmental Protection (DEP) and Biscayne Bay National Park. A preliminary report on the testing program shall be submitted by January 15, 2011. Following completion of the pilot testing program, the parties shall agree on the water quality treatment required and the feasibility, as defined in Section 3.2.3.2 of the Basis of Review for Water Use, of this project on or before January 15, 2012. Extension of this deadline may be issued in writing by the District upon demonstration of good cause such as events beyond the control of the permittee or after consideration of the results/data collected, the District determines that additional testing is necessary. In determining the water quality needed, the parties will consider State and Federal water quality discharge standards, the volume and timing of water to be delivered to Biscayne Bay and the location of delivery. In the event the parties do not reach agreement on the feasibility by January 15, 2012, the Permittee shall begin development of an alternate reuse project from the South District wastewater facility and shall provide the District with a proposal for an alternate project including a conceptual design and schedule for implementation on or before December 15, 2012.

46.

The permittee may request temporary authorization from the District to capture and store stormwater via withdrawals from the permitted Biscayne aquifer production wells, for storage within the Floridan aquifer system consistent with their Department of Environmental Protection (DEP) issued Underground Injection Control permits.The District will consider the availability of stormwater that is not otherwise needed for environmental protection or enhancement and is in no way bound to authorize such requests. All such requests shall be made in writing to the Director of Water Use Regulation.

47. Permittee shall maintain an accurate flow meter at the intake of the water treatment plant for the purpose of measuring daily inflow of water.

Permittee shall maintain a calibrated flow meter(s) at the intake (raw water) and discharge (treated water) points within the Hialeah/Preston, Alexander Orr, and proposed Hialeah RO and South Miami Heights water treatment plants for the purpose of measuring treatment losses and shall submit monthly data quarterly as required pursuant to Limited Condition # 18.

48. The Water Conservation Plan required by Section 2.6.1 of the Basis of Review for Water Use Permit Applications within the South Florida Water Management District, must be implemented in accordance with the approved implementation schedule.

The Water Conservation Plan is contained in Exhibit 18. The permittee shall submit an annual report covering water conservation activities during the prior calendar year by March 15 of each year describing water conservation activities for the year including expenditures, projects undertaken and estimated water savings.

49.

Permittee shall determine unaccounted-for distribution system losses on a quarterly basis and report the findings on an annual basis. The losses shall be determined for the entire system and for each of the water treatment plants (comparing water pumped from the wells compared to the volume into and out of the treatment plant), utilizing the most recent, approved water accounting and IWA/AWWA water audit methodologies. The permittee shall verify the IWA/AWWA water audit methods to be used with the District for the subsequent year in each annual report. The annual report shall cover activities during the prior calendar year and be submitted on March 15 of each year. In addition to the unaccounted-for loss data, the report shall include the status of the activities (actions and expenditures along with the associated water savings) completed during the year to implement the approved water loss reduction plan (Exhibit 17). In the event that the water losses, as defined by the AWWA method (Exhibit 16B), exceed 10 percent, the permittee shall include in the annual report a description of additional actions which will be implemented the following year(s) to reduce the losses to less than ten percent. If the District concludes that the progress towards achieving losses of less than 10 percent as identified in the unaccounted for losses plan is inconsistent with the plan schedule, the Permittee shall be required to revise the plan, to be approved by the District.

50.

All annual reports required in these limiting conditions shall address activities that occurred during a calendar year and shall be submitted to Water Use Compliance on or before March 15th of the following year.

51.

If it is determined that the conditions for permit issuance are no longer met for the 20 year permit duration, the permittee shall obtain a modification of the Permit from the District as necessary to come into compliance with the conditions for permit issuance. Such conditions for permit issuance include minimum flows and levels, water reservations, and other conditions ensuring the use does not cause water resource harm and is consistent with the objectives of the District, including implementation of the Comprehensive Everglades Restoration Plan.

52.

The permittee shall operate the West Wellfield in accordance with the Memorandum of Understanding between the U.S. Department of the Interior, the Governor of the State of Florida, Miami Dade County and the District incorporated in Exhibit 35.

Application No. 091228-14

(Miami-Dade Consolidated P W S)

Location:	Miami-Dade County,	S-/T53S/R41E
		S-/T54S/R39E
		S-/T54S/R40E
		S-/T54S/R41E
		S-/T54S/R42E
		S-/T55S/R39E
		S-/T55S/R40E
		S-/T56S/R38E
		S-/T56S/R39E
		S-/T57S/R38E
		S-/T57S/R39E
		S-/T57S/R40E

Appendix B

CY 2011 IWA/AWWA Audit

AWWA WLCC Free Water Audit Software: Reporting Worksheet

WAS v4.1

Back to Instructions

? Click to access definition

Water Audit Report for: MIAMI DADE WATER & SEWER DEPARTMENT
Reporting Year: 2011 1/2011 - 12/2011

Please enter data in the white cells below. Where available, metered values should be used; if metered values are unavailable please estimate a value. Indicate your confidence in the accuracy of the input data by grading each component (1-10) using the drop-down list to the left of the input cell. Hover the mouse over the cell to obtain a description of the grades

All volumes to be entered as: MILLION GALLONS (US) PER YEAR

WATER SUPPLIED

<< Enter grading in column 'E'

Volume from own sources:	?	8	112,912.331	Million gallons (US)/yr (MG/Yr)
Master meter error adjustment (enter positive value):	?	5	1,576.048	under-registered MG/Yr
Water imported:	?	8	169.252	MG/Yr
Water exported:	?	8	24,031.346	MG/Yr
WATER SUPPLIED:			90,626.285	MG/Yr

AUTHORIZED CONSUMPTION

Click here: ?
for help using option buttons below

Billed metered:	?	8	63,238.368	MG/Yr
Billed unmetered:	?	n/a	0.000	MG/Yr
Unbilled metered:	?	7	17.359	MG/Yr
Unbilled unmetered:	?	7	168.720	MG/Yr
AUTHORIZED CONSUMPTION:	?		63,424.447	MG/Yr

Pcnt: Value:
○ ● 168.720

Use buttons to select percentage of water supplied
OR
value

WATER LOSSES (Water Supplied - Authorized Consumption)

27,201.838 MG/Yr

Apparent Losses

Unauthorized consumption:	?	5	282.281	MG/Yr
Customer metering inaccuracies:	?	7	3,927.137	MG/Yr
Systematic data handling errors:	?	5	2,827.040	MG/Yr
Apparent Losses:	?		7,036.458	

Pcnt: Value:
○ ● 282.281

○ ● 3,927.137

Choose this option to enter a percentage of billed metered consumption. This is NOT a default value ?

Real Losses (Current Annual Real Losses or CARL)

Real Losses = Water Losses - Apparent Losses:	?		20,165.380	MG/Yr
WATER LOSSES:			27,201.838	MG/Yr

NON-REVENUE WATER

NON-REVENUE WATER:	?		27,387.917	MG/Yr

= Total Water Loss + Unbilled Metered + Unbilled Unmetered

SYSTEM DATA

Length of mains:	?	8	5,774.0	miles
Number of active AND inactive service connections:	?	8	436,882	
Connection density:			76	conn./mile main
Average length of customer service line:	?	5	12.0	ft (pipe length between curbstop and customer meter or property boundary)
Average operating pressure:	?	8	65.2	psi

COST DATA

Total annual cost of operating water system:	?	8	$157,724,891	$/Year
Customer retail unit cost (applied to Apparent Losses):	?	8	$4.01	$/1000 gallons (US)
Variable production cost (applied to Real Losses):	?	8	$686.56	$/Million gallons

PERFORMANCE INDICATORS

Financial Indicators

Non-revenue water as percent by volume of Water Supplied:	30.2%	
Non-revenue water as percent by cost of operating system:	26.7%	
Annual cost of Apparent Losses:	$28,216,195	
Annual cost of Real Losses:	$13,844,744	

Operational Efficiency Indicators

Apparent Losses per service connection per day:	44.13	gallons/connection/day
Real Losses per service connection per day*:	126.46	gallons/connection/day
Real Losses per length of main per day*:	N/A	
Real Losses per service connection per day per psi pressure:	1.94	gallons/connection/day/psi
? Unavoidable Annual Real Losses (UARL):	2,480.14	million gallons/year
From Above, Real Losses = Current Annual Real Losses (CARL):	20,165.38	million gallons/year
? Infrastructure Leakage Index (ILI) [CARL/UARL]:	8.13	

* only the most applicable of these two indicators will be calculated

WATER AUDIT DATA VALIDITY SCORE:

***** YOUR SCORE IS: 73 out of 100 *****

A weighted scale for the components of consumption and water loss is included in the calculation of the Water Audit Data Validity Score

PRIORITY AREAS FOR ATTENTION:

Based on the information provided, audit accuracy can be improved by addressing the following components:

1: Volume from own sources
2: Master meter error adjustment
3: Unauthorized consumption

For more information, click here to see the Grading Matrix worksheet

AWWA WLCC Free Water Audit Software: Water Balance

WAS v4.1

Water Audit Report For: DEPARTMENT

Report Yr: 2011

<table>
<tr><td rowspan="8">Own Sources
(Adjusted for known errors)
114,488.379</td><td>Water Exported
24,031.346</td><td colspan="4">Billed Water Exported</td></tr>
<tr><td rowspan="10">Water Supplied
90,626.285</td><td rowspan="4">Authorized Consumption
63,424.447</td><td rowspan="2">Billed Authorized Consumption
63,238.368</td><td>Billed Metered Consumption (inc. water exported)
63,238.368</td><td rowspan="2">Revenue Water
63,238.368</td></tr>
<tr><td>Billed Unmetered Consumption
0.000</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption
186.079</td><td>Unbilled Metered Consumption
17.359</td><td rowspan="8">Non-Revenue Water (NRW)
27,387.917</td></tr>
<tr><td>Unbilled Unmetered Consumption
168.720</td></tr>
<tr><td rowspan="6">Water Losses
27,201.838</td><td rowspan="3">Apparent Losses
7,036.458</td><td>Unauthorized Consumption
282.281</td></tr>
<tr><td>Customer Metering Inaccuracies
3,927.137</td></tr>
<tr><td>Systematic Data Handling Errors
2,827.040</td></tr>
<tr><td rowspan="3">Water Imported
169.252</td><td rowspan="3">Real Losses
20,165.380</td><td>Leakage on Transmission and/or Distribution Mains
Not broken down</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks
Not broken down</td></tr>
<tr><td>Leakage on Service Connections
Not broken down</td></tr>
</table>

Appendix C

Condition Assessment of Prestressed Concrete Cylinder Pipe (PCCP)

MIAMI-DADE WATER AND SEWER DEPARTMENT

Condition Assessment of Prestressed Concrete Cylinder Pipe

48-inch SW Well Field Supply Main – *Contract SW 22*
60-inch SW Well Field Supply Main – *Contract 343*
72-inch SW 64th Street Transmission Main – *Contract 419*

November 2011 – *FINAL REPORT*

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Pure Technologies US, Inc. ("Pure Technologies") was contracted to provide inspection and condition assessment services for several portions of the Miami-Dade Water and Sewer Department's ("WASD") prestressed concrete cylinder pipe ("PCCP") Transmission Mains. The 48 and 60-inch PCCP supply mains convey raw water from the SW Well Field to the Alexander Orr Junior Treatment Plant. The 72-inch PCCP transmission main conveys potable water from the treatment plant to the surrounding areas. Table ES1 lists the multiple mains, the dates that they were inspected, and their associated contract numbers. This report details and expands on the results presented in Pure Technologies' Summary Letter Reports dated June 13, 2011, July 18, 2011, and August 3, 2011.

Table ES1. Mains Inspected Under Agreement Number PPIC AGM-20101028

Date	Pipeline	Contract Number
April 27, 2011	48-inch SW Well Field Supply Main	SW 22
April 29 & May 26, 2011	60-inch SW Well Field Supply Main	343
May 26, 2011	72-inch SW 64th Street Transmission Main	419

<u>48-inch SW Well Field Supply Main</u>

The internal inspection performed by Pure Technologies included an electromagnetic survey of 1,228 pipes, or 3.69 miles of pipeline. A length of 0.16 miles of the inspection included 36 and 42-inch diameter PCCP. Two (2) pipes (less than 1%) within the 48-inch portion of the main were found with electromagnetic anomalies resembling broken wire wraps. No distressed pipes were detected within the 36 and 42-inch portions. In addition, the SmartBall leak detection survey detected no anomalies resembling leaks in the main.

60-inch SW Well Field Supply Main

The internal inspection, performed by Pure Technologies in two separate mobilizations, included an electromagnetic survey of a total of 954 pipes, or 3.48 miles of pipeline. Twenty-one (21) pipes (2.2%) were found with electromagnetic anomalies resembling broken wire wraps. In addition, the SmartBall leak detection survey detected no anomalies resembling leaks in the main.

72-inch SW 64th Street Transmission Main

The internal inspection performed by Pure Technologies included an electromagnetic survey of 132 pipes, or 0.47 miles of pipeline. Six (6) pipes (4.5%) were found with electromagnetic anomalies resembling broken wire wraps. As of the date of this report the SmartBall leak detection survey has not yet been completed within the 72-inch transmission main. Results from the leak detection survey will be released upon completion of the inspection and added to this report.

Table ES2 lists the summary of the electromagnetic survey results.

Table ES2. Summary of Electromagnetic Survey Results

Transmission Main	Length of Inspection (mi)	Number of Inspected Pipes	Distressed Pipes	Distressed Percentage (%)
48-inch	3.69	1,228	2	0.2
60-inch	3.48	954	21	2.2
72-inch	0.47	132	6	4.5

Pure Technologies has typically observed pipelines with similar characteristics exhibit broken prestressing wire wraps on 4% to 6% of the pipes. The percentage of pipes with electromagnetic anomalies consistent with broken prestressing wire wraps within the 48 and 60-inch mains was lower than what is typically found, while the distress rate in the 72-inch main was within the typical range.

Several variables affect the structural significance of broken wire wraps in PCCP. A structural evaluation was performed to evaluate the variables and to determine the risk of failure for pipe sections with wire break damage. As part of the condition assessment task, Pure Technologies utilized its engineering subsidiary, Openaka, Inc. ("Openaka"), to conduct a structural analysis for each of the subject transmission mains. This structural analysis evaluated the impact of an increasing number of broken prestressing wire wraps on the performance of the pipe and the corresponding risk of failure as a result of this damage.

On August 26, 2011, an external forensic evaluation was performed by Openaka on Pipe 3423 of the 60-inch SW Well Field Supply Main. The purpose of the investigation was to sample the PCCP materials in an effort to better understand the current condition of the 60-inch main. In addition, broken prestressing wire wrap counts were recorded and compared with the electromagnetic data. The structural analysis was subsequently updated based on measurements taken in the field. Samples collected from Pipe 3423 were sent to the laboratory for analysis.

Petrographic analysis was performed on one (1) 60-inch mortar coating sample by Construction Materials Consultants, Inc. ("CMC"). The analysis determined that the mortar was performing as intended and that the overall condition of the mortar coating was adequate to protect the steel prestressing wires from corrosion.

Metallurgical testing was performed on one (1) sample of the 60-inch prestressing wire and one (1) sample of the steel cylinder by Lewis Engineering, Inc. ("Lewis Engineering"). The prestressing wire from Pipe 3423 had a tensile strength corresponding to 6-gage "Class II" wire, as it broke prematurely due to pre-existing extensive hydrogen embrittlement cracking. From the torsion test and hydrogen embrittlement sensitivity test, Lewis Engineering determined that the wire performed more in accordance with what is typically observed in "Class IV" prestressing wire. Overall, Lewis Engineering found the prestressing wire from Pipe 3423 to be of poor quality with a severe degree of hydrogen embrittlement sensitivity. Tensile testing of the steel cylinder, across the base metal and across the weld, produced results in compliance with all of the allowable steel cylinder specifications in place at the time of manufacture.

Concrete compressive strength testing was performed on a sample of the 60-inch outer concrete core of Pipe 3423 by SOR Testing Laboratories, Inc. ("SOR"). The concrete core was found to have a very high compressive strength and to be of sound quality.

The leak detection and electromagnetic survey results along with subsequent structural analysis and external forensic investigation concludes the following:

- Of the two (2) distressed pipes identified on the 48-inch SW Well Field Supply Main, none were found to be in a state of incipient failure. The two pipes, Pipe 2023 and Pipe 2042, were identified with a low level of distress. The SmartBall leak detection survey did not detect any anomalies representing leaks in the main. Based on the leak detection survey, electromagnetic inspection and structural analysis, the 48-inch SW Well Field Supply Main, including the 36 and 42-inch portions, was found to be in satisfactory condition.

- Of the 21 distressed pipes identified on the 60-inch SW Well Field Supply Main, two (2) pipes, Pipe 4213 and Pipe 4210 were found to be in a state of incipient failure, identified with distress spanning their entire length. In addition, Pipe 3423 was also found to be in a state of incipient failure, containing 25 broken wire wraps. The number and location of prestressing wire breaks was verified during the external forensic evaluation. The actual number and location of prestressing wire breaks correlated very closely with the electromagnetic estimates. Laboratory testing confirmed that the concrete core, mortar coating, and steel cylinder on Pipe 3423 were of good quality. However, the prestressing wires were found to be highly susceptible to hydrogen embrittlement failure. The remaining 18 pipes contained 15 broken wire wraps or less, placing them at a low level of distress. Based on the current American Water Works Association ("AWWA") C304 PCCP Design Standard, the structural analysis concluded that the 60-inch supply main is operating beyond its design capabilities, failing to meet the serviceability requirement that governs the concrete core to steel cylinder radial tension. It should be noted that subsequent laboratory testing confirmed the concrete core to be of a much higher compressive strength than anticipated during the structural analysis, placing its actual performance beyond what was theoretically calculated. Recent pressure data provided by WASD has revealed that the normal operating pressure within the main is maintained at 15 psi with little to no pressure fluctuations. If the 60-inch main continues to be operated at or around an operating pressure of 15 psi, the risks associated with the design should be minimal. However, it remains important that transient pressures continue to be monitored and recorded to obtain accurate knowledge of the condition and rehabilitation management of the remaining distressed pipes. The SmartBall leak detection survey did not detect any anomalies representing leaks in the main.

- Of the six (6) distressed pipes identified on the 72-inch SW 64th Street Transmission Main, four (4) pipes, Pipes 1829, 1846, 1835, and 1788, were found to be in a state of incipient failure, identified with distress spanning their entire length and/or large areas of broken wire wraps. In addition, Pipe 1847 was identified with a moderate level of distress, containing 30 broken wire wraps, placing it more than half way to the Yield

Limit state under normal operating pressures. It should be noted, Pipe 1847 contains an air release valve, centered within the broken wire zone. In addition, based on the current AWWA C304 Design Standard, the structural analysis concluded that the 72-inch transmission main is operating beyond its design capabilities. Similar to that of the 60-inch supply main, the 72-inch transmission main fails to meet the Serviceability Limit state which governs the concrete core to steel cylinder radial tension. Pipe 1820 was measured to have five (5) broken wire wraps, corresponding to a low level of distress.

WASD has already begun rehabilitation and replacement efforts to mitigate the risk associated with Pipes 4213, 4210, and 3423 within the 60-inch SW Well Field Supply Main; and Pipes 1829, 1846, 1835, and 1788 within the 72-inch SW 64th Street Transmission Main.

Recommendations for the long term management of the three subject mains were developed as a result of a comprehensive inspection, engineering analysis, and condition assessment of each pipe section within each of the three mains:

- The initial inspection program establishes a baseline condition of each transmission main. In order to gather data on the rate of deterioration of the asset, it is necessary to conduct periodic inspections or develop an active monitoring of the mains. To safely manage the assets and minimize the risk of future failures, WASD should take the following actions:

    1. Rehabilitate or replace seven (7) pipes, three (3) pipes from the 60-inch SW Well Field Supply Main along with four (4) pipes from the 72-inch SW 64th Street Transmission Main, that were found to be in a state of incipient failure, prior to returning the two transmission mains to service. As discussed above, WASD has already initiated rehabilitation efforts to mitigate the risk of these seven (7) pipe sections through internal carbon fiber reinforcement or replacement.

    2. Based on the inspection and structural evaluation of the subject transmission mains, a substantial risk of failure persists if replacement or rehabilitation of the above mentioned seven (7) pipes is not completed.

    3. Pipe 1847 from the 72-inch 64th Street Transmission Main was categorized with a moderate level of distress, containing 30 broken wire wraps. Finite element modeling of the 72-inch embedded pipe design calculated that the Yield Limit State will be reached when a pipe has experienced 55 contiguous broken wire wraps at an operational pressure of 75 psi, and 37 contiguous broken wire wraps during a surge event totaling 115 psi. Openaka recommends that the risk associated with any particular pipe section should be mitigated when the total number of broken wire wraps places it at or above the Yield Limit State. It should be noted that Pipe 1847 contains an air release valve, centered within the broken wire zone. Openaka does not recommend rehabilitation but suggests future monitoring of Pipe 1847. If wire break activity has increased on Pipe 1847, it will need to be rehabilitated at that time.

4. Pipeline Management: The remaining pipe sections categorized with low levels of distress are not recommended for repair at this time. The rate of wire break activity can vary significantly depending on a number of variables. As a result, and since these pipelines are a critical asset with a high consequence of failure, it is recommended that WASD implement procedures to proactively manage the transmission main system via acoustic monitoring. An acoustic monitoring system will detect and report wire breaks as they occur in near real time. This information is combined with the electromagnetic inspection data to allow WASD to analyze the condition of the mains (i.e., the number of broken wire wraps on each pipe section). This is the best available option to minimize the risk of future pipeline failure combined with proactive rehabilitations. If an acoustic monitoring system is not implemented, Pure Technologies recommends re-inspection of the subject transmission mains within 3 years to monitor distress rates of growth and to identify additional pipes of concern.

5. Validation and Forensic Investigation: If any of the additional high priority pipe sections are located in areas where excavation is practical, it is recommended that a validation and forensic evaluation be performed while the pipe is out of service. This would involve excavating the pipeline and performing a detailed investigation of the pipe to confirm the extent of wire break damage. In addition, the groundwater, soil, and pipe constituents should be sampled and analyzed. This work should be carried out to meet two objectives:

   Validation: There are several variables that affect the accuracy of electromagnetic inspection. Validation compares the predicted level of wire break damage to the actual numbers of wire wraps to evaluate these variables. If necessary, the validation is used to adjust the electromagnetic results.

   Deterioration Mechanism: By examining the pipe and sampling the various components that contribute to the longevity of the pipeline, a determination can be made as to why a pipe section is experiencing accelerated deterioration. This information combined with the inspection information in this report, will enable WASD to determine how best to manage the subject mains to minimize the likelihood of future pipeline failure.

   More specifically, as in the 60-inch forensic evaluation of Pipe 3423, Pure recommends examination and testing of the concrete core within the 72-inch SW 64th Street Transmission Main. In addition to the concrete core testing, measurements will be taken that compare wire spacing, wraps per foot, mortar thickness, steel cylinder thickness etc. The findings would then be compared to the original design specification and subsequent structural analysis results, which determined that the resultant tension in the concrete core during operation is greater than that required to initiate micro-cracking in the core. External destructive and non-destructive techniques will provide Pure and WASD a better understanding of the current condition of the 72-inch main and its future management strategies. External evaluation methods should be implemented wherever applicable among all of WASD's mains.

6. If external testing of the 72-inch main is not available, Pure recommends entering the pipeline while it is out of service to perform an internal visual and sounding inspection within the available limits surrounding the high priority distressed pipes. Cracking in the concrete core and delaminations due to broken prestressing wire wraps can be documented and studied. Ultimately, internal inspection, coupled with external evaluation, will provide Pure and WASD with the best understanding of the current condition of the 72-inch main.

7. Pressure: The structural evaluation assumed an operating pressure plus surge totaling 60 psi within the 48 and 60-inch SW Well Field Supply Mains, and 115 psi within the 72-inch 64th Street Transmission Main. In regards to the 48-inch supply main, the internal operating plus surge pressure of 60 psi is theoretically below the level required to cause a failure of the steel cylinder, without the presence of prestressing wires. Due to potential deterioration and reduction in structural capacity of the steel, WASD should not rely on the structural capacity of the steel cylinder alone to support the internal operating pressure within this main. However, in the 60-inch supply main an operating plus surge pressure totaling 60 psi is greater than that required to cause yielding of the PCCP when under the influence of any amount of broken prestressing wire wraps. Recent SCADA data received from WASD (August 3-9, 2011) shows a steady operating pressure of 15 psi with minimal transient pressure fluctuations. WASD should be able to safely manage the structural capabilities of the 60-inch main if the operating pressures remain consistent at 15 psi. It is recommended that surge events within the 60-inch supply main be managed if they exceed 30 psi. Pressure monitoring within each of the subject mains is recommended in order to understand the effects of transient pressures on PCCP with broken prestressing wire wraps.

8. Leak detection surveys should be performed within the subject mains in three years to determine if joint leaks have developed within the subject mains. Joint leaks in PCCP are often precursors to failures and early detection can prevent future pipe ruptures.

- If the above mentioned recommendations are followed, the probability of failure within the next five years is low, and the remaining useful service life of the mains may be extended. A more definitive estimate can be provided after a follow-up inspection is conducted. This inspection will provide data to understand the rate of deterioration, allowing a more qualified calculation of the remaining useful life of the pipelines. In addition, the deterioration rates will allow WASD to effectively manage the risk of potential failure in the future.

1. Introduction/Background

1.1. Project Background and Pipeline Data

The 48-inch SW Well Field Supply Main is comprised of lined cylinder PCCP and was installed under Contract SW 22. Pipes within Contract SW 22 were manufactured by Price Brothers Company of Dayton, Ohio ("Price Brothers") in 1948.

The 60-inch SW Well Field Supply Main is comprised of embedded cylinder PCCP and was installed primarily under Contract 343. Pipes within Contract 343 were manufactured by Price Brothers in 1971. It should be noted that the Price Brothers design specification supplied by WASD is approved and signed as "Contract 342." For the purposes of this report, it is assumed that WASD provided the correct specification and that the engineer's handwriting is inaccurate. Approximately 37 pipes or 735 feet, from Station 178+03 to Station 185+38, of the 60-inch main were without contract documents at the time of this report. It should be noted that this section leads into the Alexander Orr Junior Treatment Plant and was identified with no distress.

The 72-inch SW 64th Street Transmission Main is comprised of 72-inch embedded cylinder PCCP and was installed under Contract 419. Pipes within Contract 419 were manufactured by Price Brothers in 1980.

Each of the above mains, owned and operated by WASD, along with the extents of the corresponding inspections, is shown in Figure 1.1

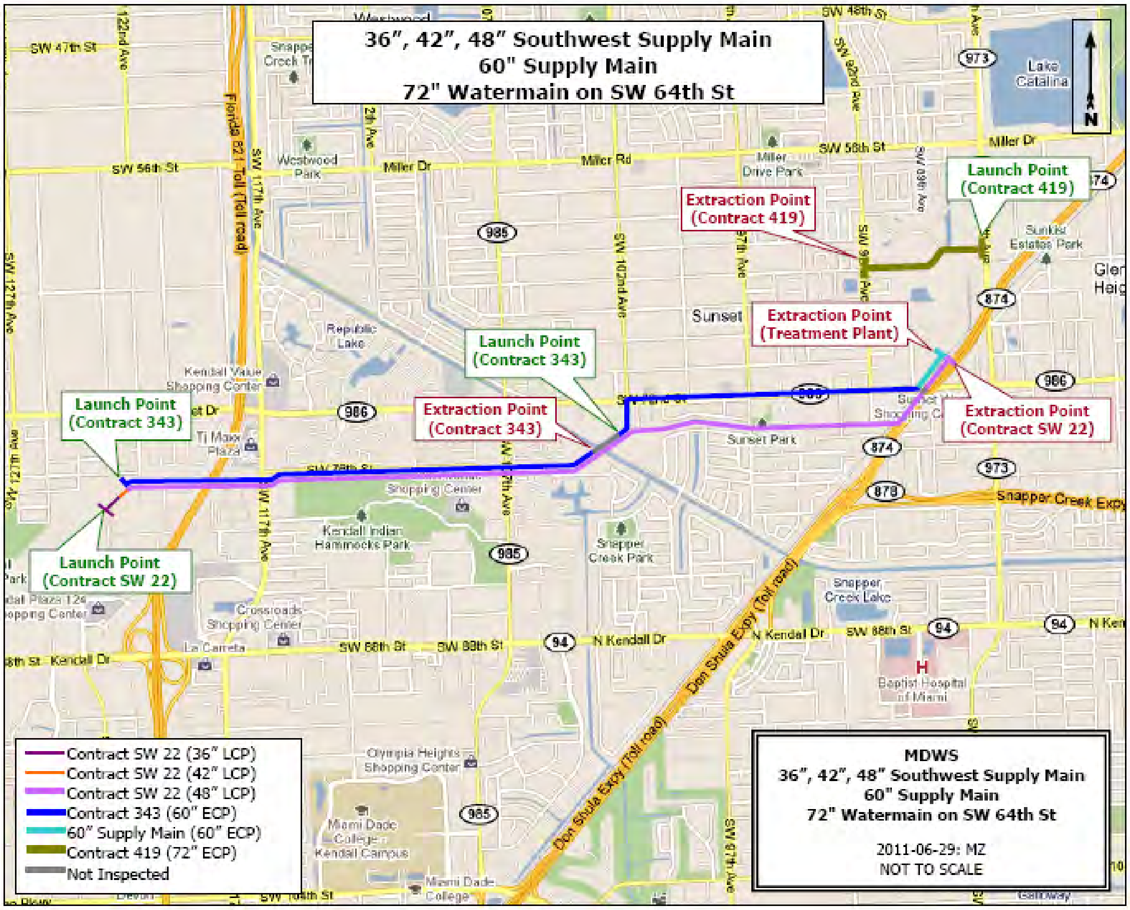


Figure 1.1 – Pipeline Map of the subject mains and corresponding inspection limits.

A comprehensive pipeline inspection, engineering analysis, and condition assessment of the mains were conducted. Specifically, an electromagnetic inspection of approximately 7.64 miles or 40,300 feet of pipeline was conducted in three (3) phases between April 27, 2011 and May 26, 2011. The inspections were conducted while the pipelines were in service via insertion and extraction of the SmartBall® and PipeDiver® technologies.

1.2. Project Scope

The overall scope of the project includes inspection of the 48-inch and 60-inch Supply and 72-inch Transmission Mains, engineering evaluation using three dimensional finite element analysis and condition assessment in order to provide pipeline management strategies for WASD. The inspection included the following investigative techniques:

Non- Destructive Inspection methods:

- SmartBall® Leak Detection survey
- PipeDiver® Electromagnetic RFTC survey
- External forensic evaluation of Pipe 3423 – 60-inch SW Well Field Supply Main

The SmartBall® is an acoustic based technology that detects anomalous acoustic activity associated with leaks or pockets of trapped gas in pressurized pipes in terms of location along the subject main. The PipeDiver® electromagnetic inspection establishes a baseline of the current condition of the prestressing wires in a pipe section in terms of the location from the joint and the quantity of broken prestressing wire wraps. External forensic evaluations correlate electromagnetic inspection estimates, provide more accurate structural analyses, and establish a better overall understanding of the current condition of the subject main. The information provided in this report is based on the different inspection methods listed above and presents the condition of the pipelines so that WASD can make appropriate decisions regarding management of the pipelines.

2. Inspection/Analysis Methodologies

2.1. Overview of PCCP

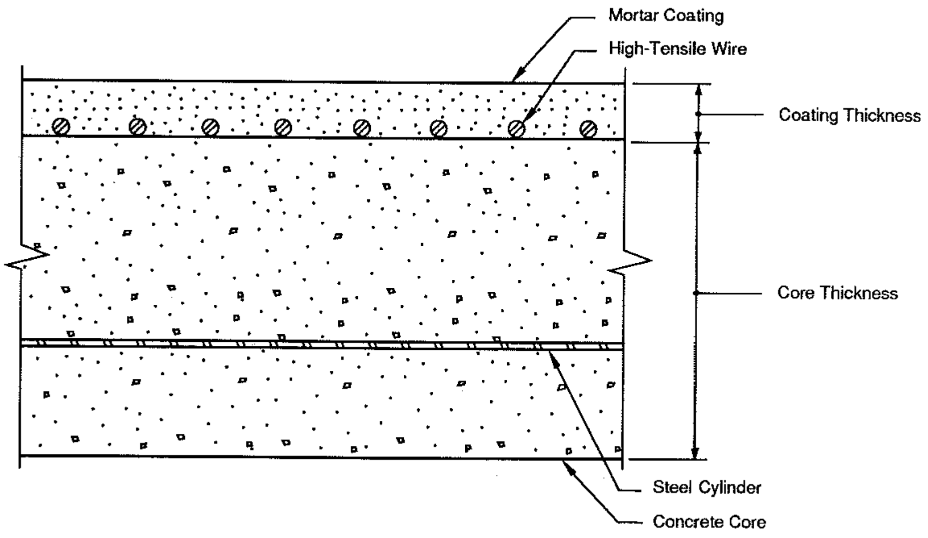
2.1.1. PCCP History/Manufacturing

PCCP has been used for large diameter water transmission and distribution mains since 1942. The first PCCP installation consisted of a design type known as lined-cylinder pipe ("LCP"). A second design type, embedded cylinder pipe ("ECP"), was developed and first installed in 1953 [1]. Cross-sectional views of LCP and ECP, as described in AWWA C304 Standard [2] are shown in Figure 2.1.

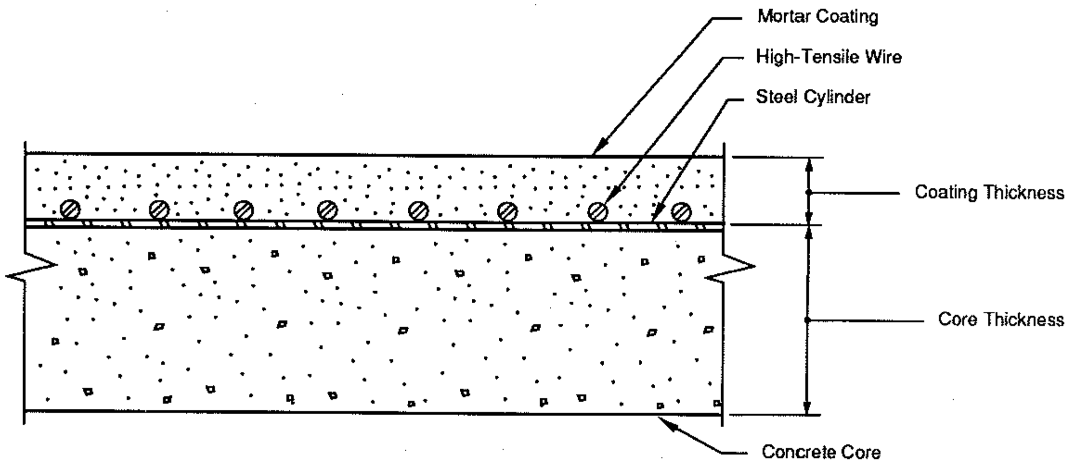
A typical ECP section consists of a concrete liner, a thin steel cylinder, concrete core, and high strength steel prestressing wires and a mortar coating. The concrete core and prestressing wire are the main structural components, with the steel cylinder acting as a water barrier. The prestressing wires produce a uniform compressive force in the core that offset tensile stresses in the pipe from the internal water pressure. A mortar coating surrounds the prestressing wires, embedding the wires in an alkaline environment to protect them from external corrosion influences (such as acidic groundwater) and also provides protection from physical damage. The prestressing wire in LCP is wrapped directly around the steel cylinder, as seen in Figure 2.1. The diameter ranges for LCP and ECP are between 16 to 60-inches and 24 to 256-inches, respectively. The subject pipelines utilize 36, 42, and 48-inch LCP along with 60 and 72-inch ECP.

PCCP design and manufacturing standards have gradually developed since 1943 with the first "tentative" consensus standard for PCCP approved by the American Water Works Association in 1949. The AWWA C301 Standard for Prestressed Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids ("AWWA C301") [3] was revised multiple times with the last revision in 2007. In 1992, the AWWA created a new standard for PCCP design and manufacturing defined as the AWWA C304 Standard for Design of Prestressed Concrete Cylinder Pipe ("AWWA C304").

The initial structural design requirements for the manufacturing of PCCP tended to be conservative [3, 4, 5] with high factors of safety. However, as experience with using this composite pipe and understanding of the behavior of PCCP increased, along with advances in material sciences, changes in the structural design of the PCCP were made to reduce the cost of manufacturing. The increase in the tensile strength of the wire during manufacturing in the late 1960's and early 1970's reduced the amount of prestressing steel wire and allowed wire of smaller diameter, which resulted in a more efficient design and economical manufacturing. These practices culminated in the 1970's when pipe utilizing Class IV wire and other cost saving measures were implemented in the manufacturing process. Pipe from this era started experiencing a high rate of premature failures.



Embedded-Cylinder Pipe



Lined-Cylinder Pipe

Figure 2.1. Cross sectional views of PCCP [1].

Subsequently, the engineering standards for PCCP began to improve, resulting in improved standards for PCCP. The major revisions in the standards, design, and manufacturing of the PCCP consist of changes in the maximum diameter of the PCCP, the quality (strength) of the concrete, the thickness of the steel cylinder, prestressing wire standards (wire diameter, wrapping stress, spacing, etc.), and the thickness of the mortar coating [3]. Figures 2.2, 2.3, and 2.4 provide graphic representations of the minimum concrete core, mortar coating and prestressing wire size as required by AWWA C301/C304 between 1949 and 2007, respectively [1].

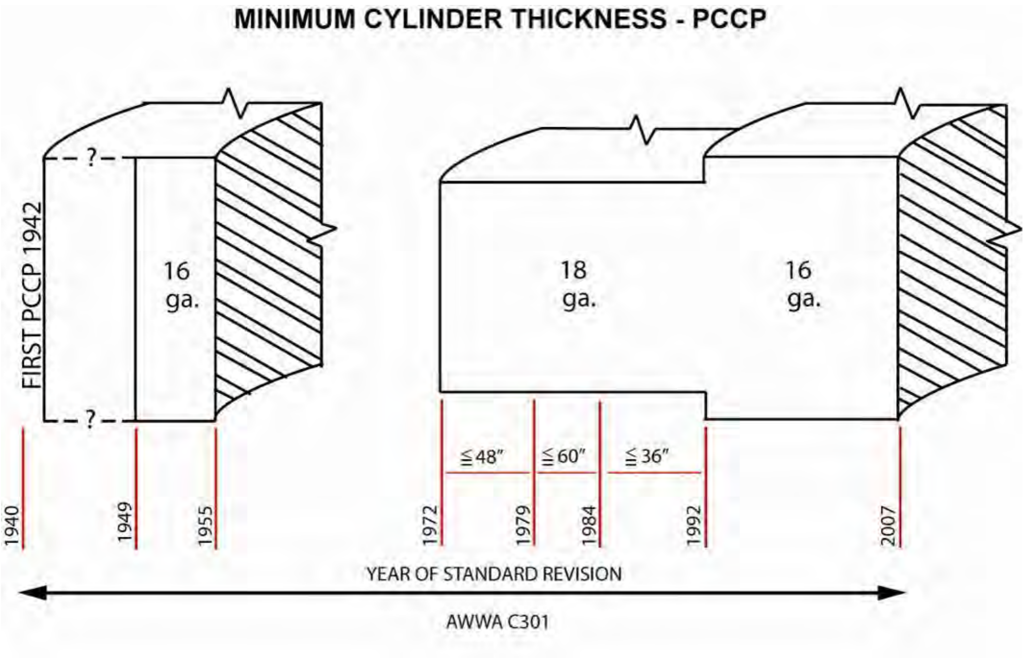


Figure 2.2. Minimum required steel cylinder thickness [1].

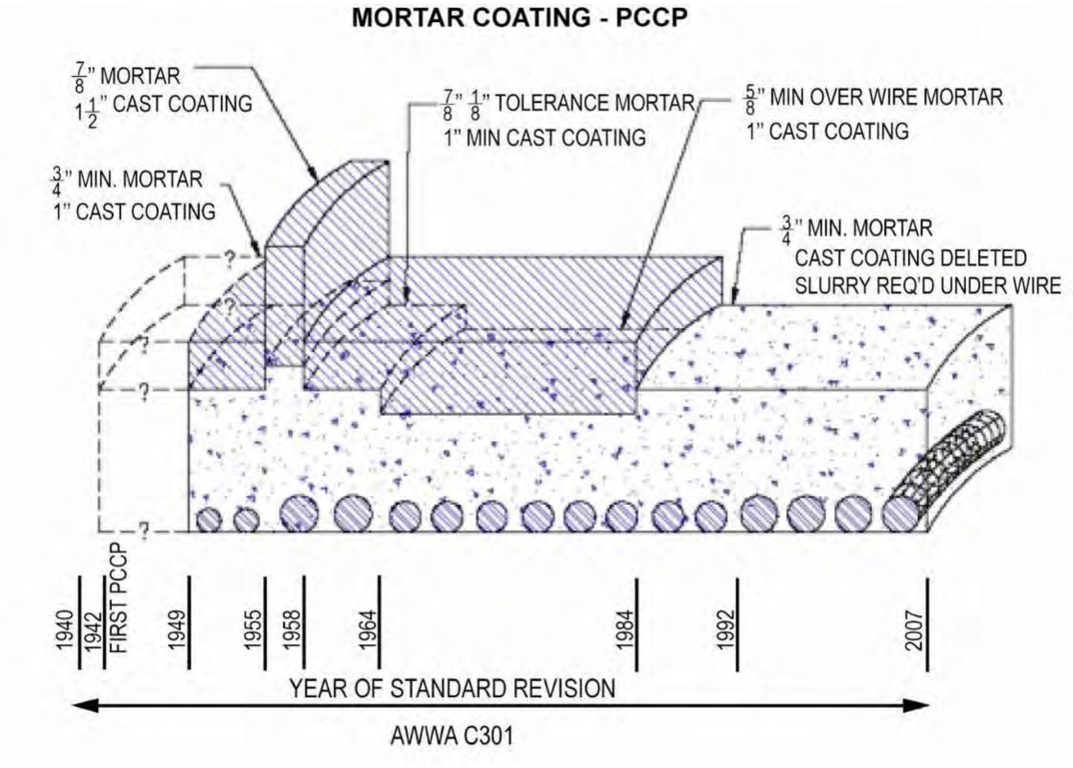


Figure 2.3. Minimum required mortar coating thickness [1].

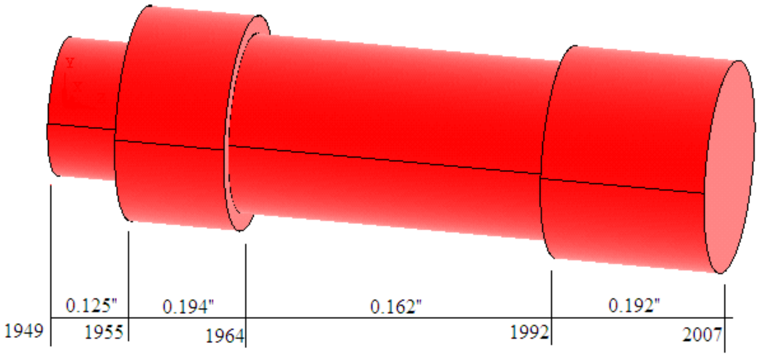


Figure 2.4. Minimum required size of prestressing wires [1].

The most influential changes in standards affecting the performance of PCCP are those related to the prestressing wires. Changes in PCCP design with respect to the prestressing wire were primarily based on updates to the American Society for Testing and Materials. (ASTM) *A227/A668 Standard Specifications for Hard-Drawn Steel Spring Wire/Standard Specification for Steel Wire, Hard Drawn for Prestressing Concrete Pipe (Current Standard – 2004)[5]*. Previous ASTM standards significantly changed the composition of the steel in the wire in order to increase the tensile strength of the prestressing wire; reducing the amount of material necessary in its manufacturing. Tensile strength is defined as the amount of stress (i.e. internal pipe pressure) the wires are able to withstand before either permanent deformation and/or failure occurs. Increasing the material strength by modifying the composition of the steel and its manufacture allowed for the reduction in the overall amount of steel necessary to achieve the minimum tensile strength for the pipe design. This allowed for a cost reduction to the pipe manufacturer and provided a cost advantage for the pipe owner. Due to the competitive cost of PCCP related to other pipe materials, its popularity grew significantly with water/wastewater utilities in the US for their large diameter pressure pipelines built in the 1950s, 1960s and 1970s.

Updates to the ASTM standard and adoption of AWWA C301-64 Standard in 1964 led to significant changes in the design and manufacture of PCCP that decreased the minimum wire size, increased the allowable concrete core stress when the wire is wrapped, reduced the amount of Portland cement in the core, and decreased the minimum coating thickness. As the ASTM standards changed and wire strength increased, classifications of wire were developed based on their tensile strength (Class I, II, and III). As the class number increases, so does the tensile strength of the wire. Both AWWA C301-64 and AWWA C301-72 required that wire was manufactured to ASTM A227 but allowed an exception for higher tensile strength wire if all other requirements of the standard are met [1]. In the 1970’s, this loophole in the ASTM and AWWA standards was used to increase the tensile strength of Class III wire. This loophole was predominantly used by the Interpace Corporation to produce Class IV wire, which had a higher tensile strength than Class III wire. To increase the tensile strength of wire, it is drawn through a die at a higher rate, which also increases the temperature of the steel due to a combination of friction and deformation. An effect known as dynamic strain aging takes place when the wire is drawn at these increased speeds and subjected to elevated temperatures. By sustaining the temperature of the steel at 356ºF for over 20 seconds, significant detrimental effects are introduced into the molecular structure of the wire. The time necessary for dynamic strain aging to take place decreases as the steel temperature increases above 356ºF. When dynamic strain aging is present, carbon and nitrogen interstitial atoms become more mobile with the increased temperature within the molecular structure of the steel allowing intercrystalline defects to develop. Hydrogen atoms can then diffuse into the steel's molecular matrix that then creates pressure from with the structure. This process increases the tensile strength of the wire but dynamic strain aging decreases the ductility of the steel. The source of hydrogen atoms may also be introduced during the manufacturing process or the result of eternal/environmental sources surrounding the PCCP. The infusion of hydrogen atoms in prestressing wire with dynamic strain aging is known as hydrogen embrittlement and is one of the primary failure modes for PCCP with Class IV wire. In light of these problems, updates to AWWA C301 beginning in 1984 have significantly improved PCCP design and manufacturing standards, increasing the quality of the pipe produced and installed. It should be noted that hydrogen embrittlement has also been observed, typically to a lesser degree, in Class III prestressing wires. Information on the expected failure rate associated with each class of prestressing wire can be found in Section 2.1.3.

2.1.2. PCCP Failure Modes

Several causes for PCCP failure were reported in the literature: a high chloride environment [6], poor quality of mortar coating [7], poor quality of prestressing wire [8, 9], a corrosive environment [10], inadequate thrust resistance [11], construction damage [12], cracks in the cylinder welds [13], and delamination of coating [13]. As each wire in a PCCP breaks, the individual pipe section's strength is incrementally reduced. A summary of PCCP failures as reported in [1] are:

- Rupture or breaks in prestressing wire wraps
- Leaking at joints
- Cracks in concrete core
- Low quality of core (poor concrete strength)
- Hydrogen sulfide (H_2S, wastewater applications)
- Dent in PCCP due to fabrication and construction defects
- Crack in cylinder welds (poor fit up)
- Low quality prestressing wire
- Overwrapping of prestressing wire, wire spaced too closely, inadequate total prestress in the pipe, or loss of prestress during manufacturing
- Wire spliced (inadequate total prestress)
- Low quality of mortar (low density, low thickness, low cement content)
- High chlorides in soil (corrosive/ aggressive soil)
- Inadequate joint restraint (pipe moved exposing joint to environment)
- Construction damage (coating damaged and not repaired)

- Coating delamination
- Hydrogen embrittlement
- Crack in joint welds
- Hydrotest pressure in excess of design pressure
- Excessive external load (greater than design load)
- Missing joint coating
- Poor bedding
- Overloading due to too much deadload and liveload during service life
- Excessive surge pressures

2.1.3. PCCP Failure Rate Probabilities by Pipe Vintage

The American Water Works Association Research Foundation completed a study on the modes of failure experienced in over 500 sections of PCCP. Category 1 failures are characterized as catastrophic failures and leaks of the main. Category 2 failure is defined as significant deterioration or structural weakness discerned by various inspection techniques including visual/sounding and electromagnetics. Figure 2.5 details the expected failure rate based on the year of manufacture. The Category 1 (Blue) failure rate for the pipe sections manufactured in 1972 to 1978 (Class IV) is significantly higher due to the poor design and manufacturing methods utilized during that time.

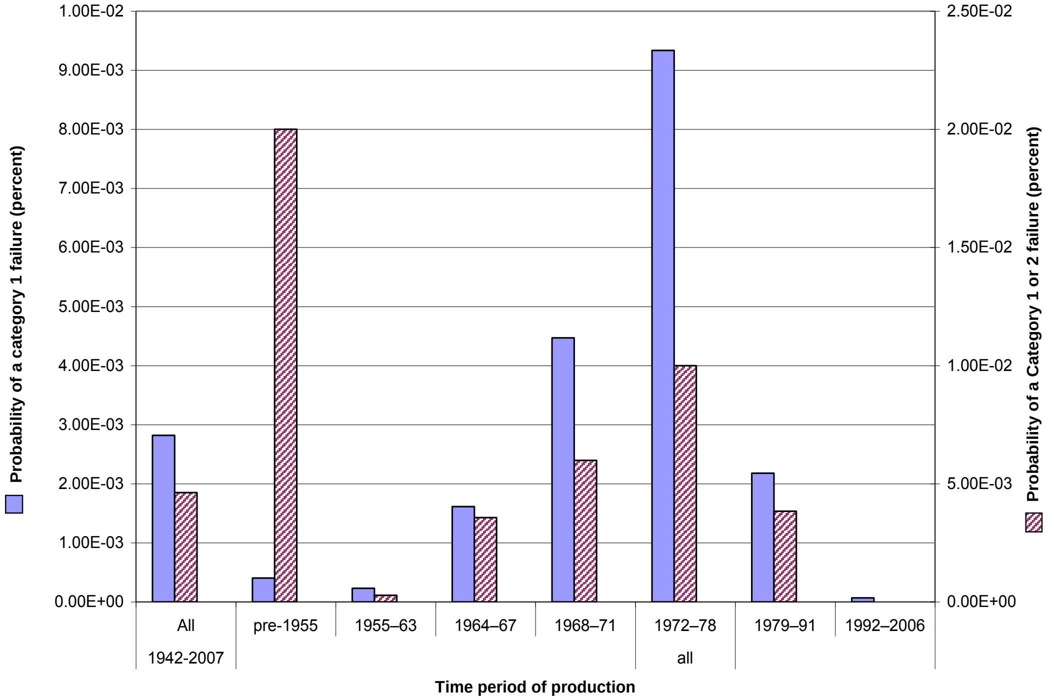


Figure 2.5. Failure of PCCP by Pipe Vintage

2.2. Inspection Techniques

2.2.1 Leak Detection Survey

SmartBall is an acoustic-based technology that detects anomalous acoustic activity associated with leaks or pockets of trapped gas in pressurized pipes. The SmartBall assembly is deployed into the flow of a pipeline, traverses the pipeline, and is captured at a point downstream. SmartBall consists of a water-tight, aluminum core that contains a power source, electronic components, and instrumentation (including an acoustic sensor, accelerometer, magnetometer, GPS synchronized ultrasonic transmitter, and temperature sensor). The core is encapsulated inside a protective outer foam shell or sphere. The outer foam shell provides additional surface area to propel the device and also eliminates noise the device might generate while traversing the pipeline. SmartBall is deployed into the water flow of a pipeline and simply travels the pipeline propelled by the hydraulic flow - and is captured at a point downstream. While the ball is traversing the pipeline, it makes a continuous recording of all the acoustic activity in the pipeline. After the SmartBall is retrieved the acoustic data is evaluated to determine the presence and location of leaks within the pipeline. The data is evaluated by detecting the sound or acoustical signature created by water discharging from a defect in a pressurized pipe. SmartBall reports are presented in Appendix A.

2.2.2. Electromagnetic Inspection

Electromagnetic inspection is a nondestructive method of evaluating the baseline condition of the prestressing wire. The PipeDiver™ electromagnetic inspection did not require taking the pipelines out of service. Electromagnetic inspections ascertain a magnetic signature for each pipe section to identify anomalies that are produced by zones of wire break damage. Various characteristics associated with an anomaly (length, magnitude, phase shift, etc.) are evaluated to provide an estimate of the number of broken wire wraps. This inspection method is able to quantify the amount of wire break damage and is the best method of determining a baseline condition of a pipeline. The electromagnetic inspection instruments have a transmitter and a receiver that are both induction coils. In a pipeline, the transmitter is driven by an AC signal. This electric current in the transmitter generates two distinct magnetic fields. The first field is direct and inside the pipe. The circumferential eddy currents induced in the conducting pipe wall attenuates this field rapidly. A second, indirect field diffuses outwardly through the pipe wall and spreads along the pipe with little attenuation. This field re-diffuses back through the pipe wall and is the dominant field inside the pipe where the detector, sufficiently spaced from the transmitter, is located. The returning field induces a voltage in the detector. Any disturbance in this indirect path causes a change in the magnitude and phase of the received signal.

During an electromagnetic inspection, the detected signal is recorded along the length of the pipeline. After the inspection, this signal is interpreted with respect to amplitude and phase. The amplitude represents the strength of the transmitted signal; the phase represents how long it takes the signal to arrive at the detector. Amplitude and phase logs are then examined to identify the start and end positions for each pipe. Fixed references (i.e.: outlets, steel sections, elbows, manholes) within the data are identified and correlated with information provided by the client.

Each pipe is then examined for distress indications which enable Pure Technologies' to compile a report wherein they rank the pipes according to level of distress, including the axial position and number of wire breaks.

Different mechanisms for transporting the inspection equipment through the pipeline are available depending on pipeline diameter and configuration and operational requirements of the utility. These platforms range from robotic unmanned, tethered and non-tethered waterproof vehicles to vehicles that require manned entry and dewatering of the pipeline. Most recently, the free-swimming PipeDiver™ technology has been specifically designed and used in live pipelines or in lines that cannot be taken out of service due to operational constraints.

Electromagnetic inspections are the most effective method to provide a baseline condition assessment of PCCP pipelines. However, studying PCCP is complex and limitations in the technology do exist. Details on the electromagnetic inspection results and technology limitations are presented in Appendix B.

2.2.3. External Forensic Evaluation

2.2.3.1 Petrographic Analysis

Petrographic examination is conducted on collected mortar and concrete core samples to investigate any defects in these components of pipe. The examination includes an analysis of the quality and condition of the mortar coating to determine its ability to protect the prestressing wires. This testing is a robust method for measuring the material characterization and supporting the failure investigation of PCCP. This method is used to examine the characteristics of the mortar coating and concrete core such as size of aggregates, type of cement, density, porosity and permeability of the material. Mortar coating samples were collected and analyzed petrographically by CMC. The petrographic examination was performed according to ASTM C865 Standard, Standard Practice for Petrographic Examination of Hardened Concrete. The specific gravity and absorption of the mortar coatings were determined according to ASTM C642, Standard Test Method for Density, Absorption, and Voids in Hardened Concrete. Chloride content of the coatings was determined according to ASTM C1152, Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete. The petrographic report provided by CMC will be presented in the appendix of this report following the completion of the laboratory testing.

2.2.3.2 Metallurgical Testing

Metallurgical testing is often performed to determine the physical properties of the prestressing wires and steel cylinder. Multiple prestressing wires were collected from Pipe 3423 for testing purposes. Metallurgical testing is being performed by Lewis Engineering. As part of the metallurgical evaluation of the wire samples, tensile tests are conducted according to ASTM A370-74 Standard Methods and Definitions for Mechanical Testing of Steel Products, Supplement IV, for Round Wire Products. Torsion tests are performed according to procedures specified in ASTM A938-97, Standard Test Method for Torsion Testing of Wire. Hydrogen embrittlement sensitivity is determined by using the European Federation Internationale de la

Precontrainte (FIP) ammonium thiocyanate test, ASTM A1032-04, Standard Test Method for Hydrogen Embrittlement Resistance for Steel Wire Hard Drawn Used for Prestressed Concrete Pipe and ASTM A648, Standard Specification for Steel Wire, Hard Drawn for Prestressed Concrete Pipe. In addition, tensile tests are performed on the steel cylinder sample across the base metal and across the weld in accordance with ASTM A370. Also, the surface of the steel cylinder and weld are examined for defects and corrosion products. Upon completion, the metallurgical results will be included in detail and the report attached to the appendix of this report.

2.3. Analysis Methodologies

2.3.1. Risk Assessment – Finite Element Analysis (FEA)

As part of the condition assessment task, Openaka generated performance curves based on the 3-D FEA models for the 48, 60, and 72-inch pipe designs. Openaka performed the structural evaluation of a pipe design under the current operating pressures and soil cover heights. WASD provided operational pressures for the subject pipelines. The maximum internal pressures considered in the analyses were considered to be 60 psi in the 48-inch and 60-inch SW Well Field Supply Mains corresponding to a 20 psi operating pressure and 40 psi surge pressure. A maximum internal pressure of 115 psi was used in the 72-inch SW 64th Street Transmission Main analysis, corresponding to a 75 psi working pressure plus 40 psi surge pressure. A trench width of the outside diameter of the pipe plus two feet was assumed, the soil was assumed to weigh 120 pcf and the value of Kμ’, the ratio of the active lateral unit pressure to the vertical unit pressure times the coefficient of friction between the fill material and the sides of the trench, was assumed equal to 0.165, which is representative of sand and gravel. The pipe bedding was assumed to be Class D, representing a bedding factor of 1.1, for pipe installed in a flat bottom trench, as the plans did not specify the pipe bedding.

The 48-inch SW Well Field Supply Main was installed under Contract SW 22. According to contract documents supplied by WASD, pipes supplied under Contract SW 22 were manufactured by Price Brothers, and installed in 1948. The design specifications supplied for the Price Brothers pipe shows three designs; one for each diameter, 36, 42, and 48-inch. A structural analysis and FEA modeling was performed for the 48-inch pipe design under normal operation conditions.

The 60-inch SW Well Field Supply Main was installed under Contract 343 in 1971. According to the available contract documents supplied by WASD and Hanson Pipe, pipe supplied under Contract 343 were manufactured by Price Brothers. It should be noted that the Price Brothers design specification supplied by WASD for the 60-inch main were, in fact, signed and labeled as Contract 342. One 60-inch pipe design was utilized in the structural analysis and FEA modeling. Two separate performance curves were established for the one design under normal operating conditions with varying levels of concrete core compressive strength. Openaka’s intital AWWA C304 results indicated that the original design, based on a concrete compressive strength of 4500 psi, failed to meet the Serviceability Limit State which governs the concrete core to steel cylinder radial tension. Further analysis was considered for a compressive strength of 5500 psi. After completing the external evaluation of Pipe 3423, Openaka performed a new AWWA C304 structural analysis based on field measurements.

The 72-inch 64th Street Transmission Main consists of embedded cylinder pipe that was designed and manufactured under Contract 419 in 1980 by Price Brothers. One 72-inch pipe design was utilized during the structural analysis and FEA modeling.

Table D.1 in Appendix D lists the Design Specifications and assumptions used by Openaka for the structural analysis and FEA modeling performed on the above mentioned transmission mains.

FEA curves were developed based on the manufacturer's design specifications and information supplied by WASD. Figure 2.6 is one of the performance curves generated for the 48-inch SW Well Field Supply Main pipe design.

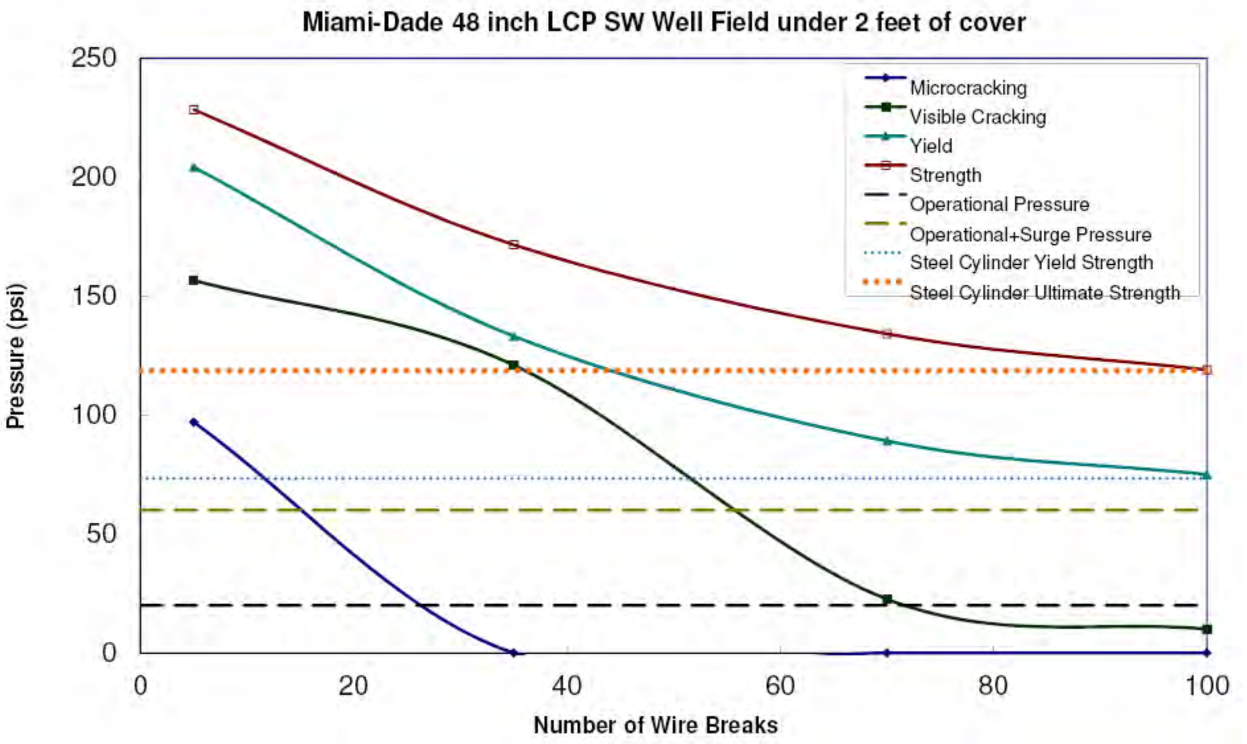


Figure 2.6 Performance Curve for 48-inch LCP SW Well Field Supply Main.

Openaka's performance curves were developed to predict the structural condition of a pipe section with wire break damage using the AWWA C301 and C304 Design Standards based on pipe specifications, typical installation methods and the known loading conditions. The performance curve for the 48-inch SW Well Field Supply Main in Figure 2.6 is provided for the lined cylinder pipe design. The pipe was evaluated under operational and surge conditions. Pressure surges, known as transients, are temporary increases (or decreases) in pipeline pressures that are often short in duration, often less than one second. Many utilities are familiar with water hammer events that cause a pipeline to fail, but most pressure transients occur unnoticed.

Pressure transients are important as they may cause fatigue of a pipeline or cause incremental damage that builds overtime, leading to failure of the pipe. As a result, it is often important to understand how pipe pressure changes with time and quantify any transients that may be occurring.

The condition of the PCCP is classified by AWWA C304 into four limit states called Micro-cracking (blue), Visible Cracking (black), Yield Limit (light blue), and Strength Limit (red). Openaka's terminology is provided in Table 2.2 and provides the general terms used to define the predicted condition of a PCCP pipe section with a known quantity of contiguous wire breaks. The actual wire break damage required to reach these conditions varies based on the pipe design, operational history and environmental conditions. The AWWA C304 defined Limit States are referred to and used consistently throughout this report.

Table 2.2 - Predicted Pipe Condition Given Wire Break Damage

Limit State	Characteristics
Micro-Cracking[1]	Cracks 0.001-inch thick and 12-inches long
Visible Cracking[1]	Cracks greater than 0.002-inch thickness, 12-inches long
Yield Limit	Prestressing Wire has reached 85% of Yield Limit Strength
Strength Limit	Prestressing Wire Ultimate Strength Reached

[1] Charcterization of cracks must be validated by field measurement

The maximum number of broken prestressing wire wraps to reach a specific pipe condition under operational and surge condition for each pipe can be calculated using the FEA performance curves.

The determination to replace an individual pipe section should be made using the Operational + Surge Pressure condition on the FEA Curve (see Figure 2.9). When the number of wire breaks is determined to reach the lower threshold of the Yield Limit wire break range, Pure Technologies recommends replacement of a pipe section. Once the wire breaks on a pipe section reaches the Yield Limit State, a pipe section may experience a higher rate of wire break damage until it reaches the Strength Limit. It should be noted that when a pipe reaches the Strength Limit it does not necessarily indicate a failure. According to the FEA performance curve in Figure 2.6, no amount of broken wire wraps will cause the pipe to reach its Yield Limit under the operational plus surge pressure conditions. Theoretically, the 48-inch design should be able to rely on the structural capacity of the steel cylinder alone under the known loading conditions.

2.3.2. Analysis

Part of the pipeline evaluation and condition assessment is to evaluate risk of PCCP structural failure due to reduced structural capacity as a result of wire break damage and concrete deterioration. The prestressing wire is a principal structural component of PCCP and each individual class of PCCP installed in a particular pipeline is designed specifically for the maximum hydraulic operating pressure and soil covers expected along the route. Thus, any amount of wire break damage poses some level of risk to the pipeline and should be carefully evaluated. In an effort to quantify risk, a structural analysis and risk evaluation was performed. It is important to recognize that the structural analysis is subject to several complex variables that cannot be modeled with 100% certainty. In order to evaluate the above modeling results and make recommendations on how to manage a particular pipeline, it is important that some of the variables affecting the structural modeling and risk are understood. The primary variables affecting the engineering analysis are detailed below.

2.3.2.1. Effects of Cover

Earth cover plays a significant role in the amount of tolerable wire break damage on a PCCP main. PCCP is designed based on a combined load design method. Increasing the amount of earth loading on a pipe originally designed for a specific combination of pressure and earth cover has the effect of reducing the pipe's capacity to contain the internal operating pressure. For instance, if a pipe is originally designed for a working pressure of 100 psi and a soil cover of 10 feet, the allowable internal pressure would need to be reduced if the soil cover over the pipe is increased beyond the design cover.

Earth loads tend to apply flexural stresses to the pipe's concrete core at the springline, invert, and crown. High earth loads due to deep soil covers will impose high flexural stresses on the pipe concrete core. Under very high soil covers and relatively low internal pressure, PCCP design is typically dominated by external soil load, quite often requiring a thicker than standard concrete core to tolerate the high flexural stresses.

2.3.2.2. Effects of Wire Bond

When a prestressing wire wrap breaks, its tension is completely released at the point of breakage. The ends of the wire retract, which react against the constrictive forces of friction being applied to the wire by the mortar coating and concrete core. These friction forces enable the wire to redevelop its tension over a relatively short distance from the point of breakage. The redevelopment length can vary from less than an inch to several feet depending on the prestress wire class and size, as well as the condition and quality of the mortar coating. If a wire breaks and quickly redevelops its tension, the structural consequence of the break is minimal. For a specific wire diameter and wire class, the primary variable affecting the redevelopment length is the wire bond to the pipe structure, i.e. the mortar coating and concrete core. If the coating is hard and relatively intact and remains well attached to the concrete core, wire bond will remain high and full tension in the wire will develop in a short distance from the point of breakage. When the coating becomes soft, cracks, or is delaminated from the core, the wire bond is reduced and the redevelopment length is increased significantly, hence reducing the pipe's main structural component over a significant area of the pipe wall.

Since it is not practical to measure the actual wire bond strength for each pipe section, a conservative assumption must be made for modeling purposes. The most conservative assumption is to remove broken wire wraps from the model all together. This is overly conservative and generally unrealistic. In this scenario, according to the structural modeling, the pipe would fail at the curve between the Visible Cracking and Yield Limit states. When the effects of wire bond are incorporated, the FEA curves predict ultimate cylinder and wire stress condition (pipe failure) would occur at the curve between Yield Limit and Strength Limit states. Using this type of curve, the percentage of wire bond is calculated at the theoretical point of pipe failure.

However, it is important to understand that if conditions exist in a pipe section that lead to a lower wire bond percentage than indicated in the curves, the models predict the pipe section would fail prior to reaching the Strength Limit state. If the mortar coating becomes delaminated, the wire may not be bonded for the entire area of the delamination. Also if the mortar is under attack and weakened/cracked by aggressive soil and groundwater conditions surrounding the pipeline, this will reduce wire bond.

2.3.3. Validation of Inspection Results

2.3.3.1. Field Observations vs. Predicted Results

It is Pure Technologies' recommendation that caution be used when viewing the performance curves as management tools for the transmission mains. These curves are useful for evaluating overall risk, but modeling such a complex situation as wire break damage on a PCCP main is not precise. When opportunities arise to excavate and inspect pipe sections in the field, the actual condition of the pipe should be compared to the estimated wire breaks and the predicted results from the structural model to determine if they are consistent with the observed conditions. Ideally, the structural modeling would produce results consistent with field observations, but with some conservatism.

During previous excavations of PCCP mains, it has been observed that structural models generally produce results that are conservative. In other words, a pipeline can tolerate much more wire break damage than predicted by the structural models due to the complex mix of conditions affecting the pipeline. This level of conservatism is important and provides reassurance in the structural modeling results. However, it is Pure Technologies's recommendation not to rely on this conservatism when evaluating the results and making recommendations based on the predicted levels of performance. If a practical management approach can be implemented based on this practice, the risk of failure should be acceptable. These management approaches are further detailed in Section 5.0.

2.3.3.2. Destructive Verification Testing

The most accurate method of determining the number of wire breaks in a section of excavated PCCP is to remove the mortar coating to permit a visual external inspection of the wires. To remove the mortar coating, a demolition saw is used to cut the crown of the pipe to a depth below the prestressing wire. This cuts the wires and releases the prestressing force to permit easy mortar removal. With the mortar removed, the prestressing wire and outer concrete core can be inspected to quantify wire breaks as well as mortar, wire, concrete core, and steel cylinder corrosion. In certain cases, a non-destructive approach can be used to chip open a strip of the mortar coating and continuity testing can be performed on the exposed wires. A broken wire wrap count can be performed and compared with electromagnetic findings. If the level of distress permits, the pipe can be patched and returned to service.

2.3.4. Risk Assessment (Consequence of Failure)

A failure in any main stem of the supply and/or transmission mains will limit potable water distribution from the Alexander Orr Junior Water Treatment Facility. Inter-connections and redundancies typically minimize the risk of interruptions. Failure of one of the transmission mains would result in an interruption and subsequent high fiscal consequences for WASD.

3. Inspection Results

3.1. Leak Detection Survey

48-inch SW Well Field Supply Main

Pure Technologies inspected approximately 19,500 feet of the 48-inch supply main utilizing its patented SmartBall leak detection technology. Pure Technologies detected two (2) acoustic anomalies that resembled leaks (simulated) and no acoustic anomalies resembling pockets of trapped gas. The detected leaks were simulated by Pure Technologies to test the SmartBall and similar leak detection equipment within the PipeDiver. The results are summarized in Table 3.1. Detailed results are contained in Appendix A of this report.

Table 3.1 Summary of 48-inch SmartBall Results

Total Length of Pipe Surveyed:	19543.0 ft.
Pipe Material:	PCCP
Diameter of Pipe:	48 inch
Product:	Raw Water
Number of Acoustic Anomalies Resembling Leaks:	2 (simulated)
Number of Acoustic Anomalies Resembling Pockets of Trapped Gas:	0
Duration of Survey:	1 hour, 49 minutes
Average SmartBall Velocity	3.0 ft/s

60-inch SW Well Field Supply Main

Pure Technologies inspected approximately 18,700 feet of the 60-inch supply main utilizing its patented SmartBall leak detection technology. Pure Technologies did not detect any anomalies resembling leaks or pockets of trapped gas within the main. The results are summarized in Table 3.2. Detailed results are contained in Appendix A of this report.

Table 3.2 Summary of 60-inch SmartBall Results

Total Length of Pipe Surveyed:	18663.0 ft.
Pipe Material:	PCCP
Diameter of Pipe:	60 inch
Product:	Raw Water
Number of Acoustic Anomalies Resembling Leaks:	0
Number of Acoustic Anomalies Resembling Pockets of Trapped Gas:	0
Duration of Survey:	6 hours, 7 minutes
Average SmartBall Velocity	0.8 ft/s

3.2. Electromagnetic Inspection

48-inch SW Well Field Supply Main

On April 27, 2011, Pure Technologies conducted a non-destructive evaluation of the 48-inch SW Well Field Supply Main that conveys raw water from the SW Well Field to the Alexander Orr Jr. Treatment Plant in Miami, FL, using its patented electromagnetic PipeDiver™ technology. The inspection measured 3.69 miles in length. A total of 1,228 pipes were tested during the inspection.

During the field work, the electromagnetic inspection recorded the magnetic signature of each pipe section as it traversed the main. This data was evaluated to identify pipes exhibiting electromagnetic anomalies resembling broken wire wraps. In addition, the spatial characteristics and magnitude of the anomalies was compared to calibration data from similar PCCP mains to determine the approximate number of broken prestressing wire wraps for each pipe section. The summary of this analysis is provided in Table 3.3.

TABLE 3.3 Summary of Electromagnetic Inspection Results

Pipeline Name	Diameter (in.)	Contract Number	Number of Inspected Pipes	Distressed Pipes	
				#	%
48-inch SW Well Field Supply Main	36	SW 22	37	0	0.00
	42		22	0	0.00
	48		1169	2	0.17
Total			**1228**	**2**	**0.16**

Based on the summary of electromagnetic inspection results, less than 1% of pipe sections surveyed exhibited electromagnetic anomalies consistent with broken wire wraps, ranging from 5 to 10. Details of the electromagnetic inspection results are provided in Appendix B of this report.

One anomalous pipe, Pipe 715, was found at Station 123+32. “Anomalous” signal observations in RFTC data do not resemble characteristics of broken prestressing wire wraps. The signal shift could be caused by an undocumented feature or property change. Additional information is required to conclusively analyze these anomalous pipes.

60-inch SW Well Field Supply Main

On April 29 and May 26, 2011, Pure Technologies conducted a non-destructive evaluation of the 60-inch SW Well Field Supply Main that conveys raw water from the SW Well Field to the Alexander Orr Jr. Treatment Plant in Miami, FL, using its patented electromagnetic PipeDiver™ technology. The inspection measured 3.48 miles in length. A total of 954 pipes were tested during the inspection.

During the field work, the electromagnetic inspection recorded the magnetic signature of each pipe section as it traversed the main. This data was evaluated to identify pipes exhibiting electromagnetic anomalies resembling broken wire wraps. In addition, the spatial characteristics and magnitude of the anomalies was compared to calibration data from similar PCCP mains to determine the approximate number of broken prestressing wire wraps for each pipe section. The summary of this analysis is provided in Table 3.4.

TABLE 3.4 Summary of Electromagnetic Inspection Results

Pipeline Name	Diameter	Contract	Number of Inspected Pipes	Distressed Pipes	
				#	%
60-inch SW Well Field Supply Main	60	343	917	21	2.29
		n/a	37	0	0.00
Total			**954**	**21**	**2.20**

Based on the summary of electromagnetic inspection results, 2.2% of pipe sections surveyed exhibited electromagnetic anomalies consistent with broken wire wraps. Typically, electromagnetic inspections identify on average 4% of pipes with broken wire wraps. Overall, the transmission main has a lower than usual number of pipes with wire break damage. Contract 343 contains all of the distressed pipes, with broken wire wraps ranging from 5 to 25. Two (2) pipes were recorded with distress across their lengths. Details of the electromagnetic inspection results are provided in Appendix B of this report.

72-inch SW 64th Street Transmission Main

On May 26, 2011, Pure Technologies conducted a non-destructive evaluation of the 72-inch transmission main that runs predominately along SW 64th Street in Miami, FL, using its patented electromagnetic PipeDiver™ technology. The inspection measured 0.47 miles in length. A total of 132 pipes were tested during the inspection.

During the field work, the electromagnetic inspection recorded the magnetic signature of each pipe section as it traversed the main. This data was evaluated to identify pipes exhibiting electromagnetic anomalies resembling broken wire wraps. In addition, the spatial characteristics and magnitude of the anomalies was compared to calibration data from similar PCCP mains to determine the approximate number of broken prestressing wire wraps for each pipe section. The summary of this analysis is provided in Table 3.5.

TABLE 3.5 Summary of Electromagnetic Inspection Results

Pipeline Name	Contract Number	Diameter (in.)	Number of Inspected Pipes	Distressed Pipes	
				#	%
72-inch SW 64th Street Transmission Main	419	72	132	6	4.55

Based on the summary of electromagnetic inspection results, 4.6% of pipe sections surveyed exhibited electromagnetic anomalies consistent with broken wire wraps. The 72-inch portion contained two (2) pipes with broken wire wraps ranging from 5 to 30. Four (4) pipes were identified with distress spanning their entire lengths. Details of the electromagnetic inspection results are provided in Appendix B of this report.

3.3 External Forensic Evaluation

3.3.1 Pipe Dissection

Based on the results of the acoustic leak detection survey, RFTC inspection, and subsequent structural analysis, Pure recommended in the August 3, 2011 letter that three (3) pipes, Pipes 4213, 4210, and 3423 be rehabilitated or replaced immediately.

In addition to the carbon fiber reinforcement of Pipe 4213 and 4210, WASD removed and replaced Pipe 3423. Pure Technologies mobilized to the project site August 26, 2011 to perform an external forensic evaluation of Pipe 3423. Following the removal, two pieces of Pipe 3423 remained – approximately seven linear feet of each of the upstream and downstream ends. Figures 3.1 and 3.2 show the remaining portions of Pipe 3423.

Figure 3.1 Downstream bell end of Pipe 3423.

Figure 3.2 Upstream spigot end of Pipe 3423.

Pure Technologies performed a visual and sounding inspection of the exterior and interior of the pipe, followed by destructive techniques to dissect the composite layers of the 60-inch PCCP. No cracking, spalling, or delaminations were observed within the inner concrete core and outer mortar coating. The remaining components appeared to be intact and well consolidated. Following the dissection, the components of the pipe were inspected, measured, and compared to the provided manufacturer's specifications. (Figures 3.3 and 3.4)

Figure 3.3 Inner concrete core measurement.

Figure 3.4 Wire spacing measurement.

Prestressing wire breaks were quantified, located and compared to the electromagnetic distress estimates. Twenty-one (21) broken wire wraps were identified on the upstream portion of the pipe, correlating well with the location of the 25 estimated from the electromagnetic survey. The wire breaks were inspected and found to be brittle in nature. Typically, brittle wire fractures, as those observed on Pipe 3423, are a result of a moderate to severe degree of hydrogen embrittlement. Hydrogen embrittlement is typically attributed to the poor techniques utilized by Interpace Corporation in the manufacturing of high strength Class IV wire. However, hydrogen embrittlement has been observed within manufactured Class III prestressing wires – as in Pipe 3423. Figures 3.5 and 3.6 show the observed brittle wire fractures.

Figure 3.5 Brittle wire fracture observed following the removal of the mortar coating.

Figure 3.6 Brittle wire fractures observed embedded in a sample of the mortar coating.

Samples of the mortar coating, outer concrete core, prestressing wires, and steel cylinder were extracted from Pipe 3423, analyzed, and sent to the laboratory for testing. Laboratory testing will determine the physical properties of the pipe components. The average mortar coating thickness was measured to be 0.5 inches. This is smaller than the manufacturer’s specified 0.875-inch thickness. The 4.5-inch concrete core was observed to be dense, hard, and without visible cracking. As mentioned, the 6-gage Class III prestressing wires were brittle in nature. No corrosion was present on the steel surfaces of the prestressing wires. The 16-gage steel cylinder was also without visible defects and/or corrosion. Each of the PCCP components was tested, beyond the limits of the onsite visual inspection, within a laboratory.

In addition, the electromagnetic data for the remaining distressed pipes was calibrated and adjusted. Based on the individual pipe that was tested, Pipe 3423, the inspection results appear to be very closely correlated and did not change dramatically to include any additional rehabilitation recommendations.

The AWWA C301/C304 structural analysis was performed using the new pipe measurements, and provided SCADA pressure data. Overall, the dissected pipe components matched the manufacturer’s specifications closely. The only observed difference was with the wire spacing which was recorded as 8.52 wraps per foot. Given the new wire spacing and recorded 15 psi working pressure, and reduced surge conditions to 40% (6 psi), the 60-inch pipe design passes all AWWA C301 and C304 structural analyses. It should be noted that the pressure data was recorded over a relatively short time period and may fluctuate beyond 40%. According to the current AWWA C304-07 Design Standard, transient pressures should be considered as 40% of the working pressure or 40 psi, whichever is greater. In that case, a working plus surge pressure of 55 psi would still cause the serviceability limit state, which governs the concrete core to cylinder radial tension, to be exceeded.

3.3.2 Petrographic Examination

The petrographic report provided by CMC is presented in Appendix C and includes an analysis of the quality and condition of the mortar coating with respect to its ability to protect the prestressing wires. The mortar coating sample was found to be non-air-entrained, dense, hard, with no evidence of separation of aggregate, micro-cracking, chemical or physical deterioration by any deleterious reactions. The sample was found to show rough, gray, weathered, carbonated, exposed outside surfaces, and fresh fractured inside surfaces with impressions of prestressing wire wraps on a wire cast surface that was free of any corrosion products. Table 3.6 summarizes the acid-soluble chloride contents of the mortar coating.

Table 3.6 - Chlorides by Mass of Cement

Sample	Location	Percent Chloride by Mass of Cement
Pipe 3423	Top	0.02
	Middle	0.03
	Bottom	0.03

In Table 3.6, top, middle, and bottom indicate the exposed surface, the interior mid-depth, and the wire cast surface of the mortar sample. The chloride contents in the body are indicative of contributions from mortar-making ingredients with negligible or no contributions from the external environment. The chloride content at the wire cast surface of the mortar is low and did not contribute to or initiate corrosion of the prestressing wire wraps in the presence of moisture and oxygen. A detailed petrographic report, provided by CMC, is attached in Appendix C of this report.

Table 3.7 summarizes the water-absorptions and volumes of permeable voids in the mortar coating sample.

Table 3.7 – Volume of Permeable Voids

Sample	Absorption After Immersion (%)	Volume Permeable Voids (%)
Pipe 3423	5.64	10.79

The cold and boiling water absorption and the resultant volume of permeable voids are consistent with a dense, non-air-entrained, well-consolidated and overall sound mortar coating.

3.3.3 Metallurgical Testing

The laboratory metallurgical testing and evaluation of Pipe 3423 was provided by Lewis Engineering and is included in Appendix D of this report. Metallurgical testing was conducted to ascertain the strength and quality of the prestressing wires and steel cylinder sampled from the adjacent pipe. The results of the testing are shown in Tables 3.8 and 3.9.

Table 3.8 - Metallurgical Testing of Prestressing Wires – Pipe 3423

Tensile Test	
Max. Load (lbf)	6,742
Ultimate Tensile Strength (ksi)	229
Initial Wire Diameter (in)	0.1938
Reduction in Area (%)	3
Torsion Test	
Initial Wire Diameter (in)	0.192
Revolutions to Failure	0.9
Torque Drop (revs)	---
Max. Torque (in-lb)	165.3
Failure Mode	Split fracture with blue temper color oxide on pre-existing split
HE Sensitivity Test	
Time to Failure (hr)	1.8
Failure Mode	Brittle fracture, with pre-existing split

Table 3.9 – 16 Gage Steel Cylinder Tensile Tests

Sample	Area (in^2)	Max Load (lbf)	Ultimate Tensile (ksi)	Yield Strength (ksi)	Tensile Elongation (%)
Base	0.0304	1,865	61.5	43.2	29
Weld	0.0302	1,599	53.0	39.7	21

The metallurgical tensile testing determined that the prestressing wire had a relatively low breaking strength at 229 ksi. This ultimate tensile strength corresponds with ASTM A648-72 Class II prestressing wire. However, it was noted that the wire failed along pre-existing dark oxide brittle splits in the wire. The lack of ductility, pre-existing longitudinal splits and transverse cracking, are all characteristics of hydrogen embrittlement sensitive Class IV wires. It should be noted that the Price Brothers specification called for a minimum tensile strength of 252 ksi, indicating 6-gage Class III wire was specified. Openaka and Lewis Engineering have observed Class III and Class IV prestressing wires exhibit similar hydrogen embrittlement charcteristics. Class IV prestressing wire has been known to be susceptible to dynamic strain aging effects and hydrogen embrittlement sensitivity due to the excessive drawing temperatures. The prestressing wire failed torsion tests after 0.9 revolutions with a split fracture. A temper color oxide could be seen on the pre-existing longitudinal split. These results further indicate a severe degree of dynamic strain aging and evidence of wire that was manufactured beyond the acceptable drawing limits. A severe degree of hydrogen embrittlement was also identified during testing, with the wire failing at 1.8 hours. Typically, good quality steel prestressing wire endures the hydrogen embrittlement testing for a minimum of 75 hours.

The steel cylinder was also tested for its tensile properties across the base metal and across the weld. Tensile tests on the base metal recorded a yield strength of 43.2 ksi and an ultimate strength of 61.5 ksi; with an elongation of 29%. The tensile properties of the steel cylinder across its weld recorded a yield strength of 39.7 ksi and an ultimate strength of 53.0 ksi; with an elongation of 21%. In this case, after welding the extraordinarily high tensile cylinder base metal, the heat effect of welding diminished the tensile properties in the heat affected zone. Overall, the steel cylinder was of an acceptable quality and in accordance with design standards and specifications. A detailed metallurgical report, provided by Lewis Engineering, is provided in Appendix D of this report.

3.3.4 Concrete Compressive Strength

Concrete compressive strength testing was performed on a sample of the 60-inch outer concrete core of Pipe 3423 by SOR Testing Laboratories, Inc. (“SOR”). The concrete core was found to have a very high compressive strength, with an average compressive strength of 8,860 psi, and, overall, to be of sound quality. A detailed report of the concrete compressive strength testing, as provided by SOR, is located in Appendix E of this report.

4. Evaluation of Risk of Failure and Structural Modeling

4.1. Pipe Properties

All pipe design specifications were available for the subject mains. In addition to the given Price Brothers design specifications, typical installation methods (i.e., trench width, bedding factor, etc.) and information provided by WASD regarding pipeline operating pressures were used in the evaluation of risk of failure and structural modeling of the mains.

4.2. Pipeline Pressure

An important input of the structural evaluation is the actual operating pressure of the pipeline, including working pressure plus transient pressure surges. WASD provided Pure Technologies the working pressure of approximately 20 psi in the 48 and 60-inch SW Well Field Supply Mains, and 75 psi in the 72-inch SW 64th Street Transmission Main. There were no results of hydraulic transient analyses available for the subject transmission mains. In addition, the modes of valve operation are unknown. Transient pressures are caused by sudden changes in pipeline flow velocity as a result of opening and closing of valves or pumps starting and stopping. Since there is no hydraulic transient analysis or pressure measurements from devices capable of detecting and measuring short duration transients, Openaka utilized a maximum transient pressure of 40% of operating pressure or 40 psi, whichever is greater, as suggested by the AWWA C304 standard, in absence of the results of a hydraulic transient analysis. The actual maximum pressure may be different from those used in this analysis, depending on the actual system operation and maintenance of valves. Pure Technologies used the maximum working-plus-transient pressure of 60 psi (20 psi working pressure and 40 psi transient pressure) and 115 psi (75 psi working pressure and 40 psi transient pressure), in the above respective mains, to determine the risk of failure of pipes with broken wire wraps.

4.3. Structural Analysis

A further breakdown of the distressed pipes shows that the number of contiguous broken wire wraps in an individual pipe section is important as it allows analysis of the risk of failure of each pipe section. Several variables affect the structural significance of wire break damage and a structural evaluation was performed to evaluate the variables and determine the risk of failure for pipe sections with wire break damage.

As part of the condition assessment task, Pure Technologies utilized its engineering subsidiary, Openaka, to generate performance curves based on the three-dimensional FEA models for the three subject transmission mains.

The 48-inch SW Well Field Supply Main was designed in 1948 prior to the introduction of the AWWA C301 Design Standard in 1964. The 60-inch SW Well Field Supply Main was manufactured and installed in 1971 in accordance with AWWA C301-64. The 72-inch SW 64th Street Transmision Main was manufactured and installed in 1980 in accordance with AWWA C301-72. The current pipe design procedure is in accordance with AWWA C304-07 and is based on meeting certain serviceability, damage, and strength limit states. A structural evaluation was performed on each pipe design class using both C301 Design Standards in place at the time of manufacturing and the current C304 Design Standard.

4.3.1. AWWA C301 Analysis

The AWWA C301 Appendix A design curve for the 60-inch SW Well Field Supply Main is shown in Figure 4.2. The blue line indicates the design curve and the green line represents the transient curve. Using the AWWA C301 Appendix A “Cubic Parabola Method”, the design for the 60-inch pipe would be satisfied under the actual loading conditions. AWWA C301, the design standard in place at the time of manufacturing, analyses concluded that each of the three mains was operating within their design limits. All structural C301 plots are contained in Appendix F, one for each of the pipe designs within the three subject transmission mains.

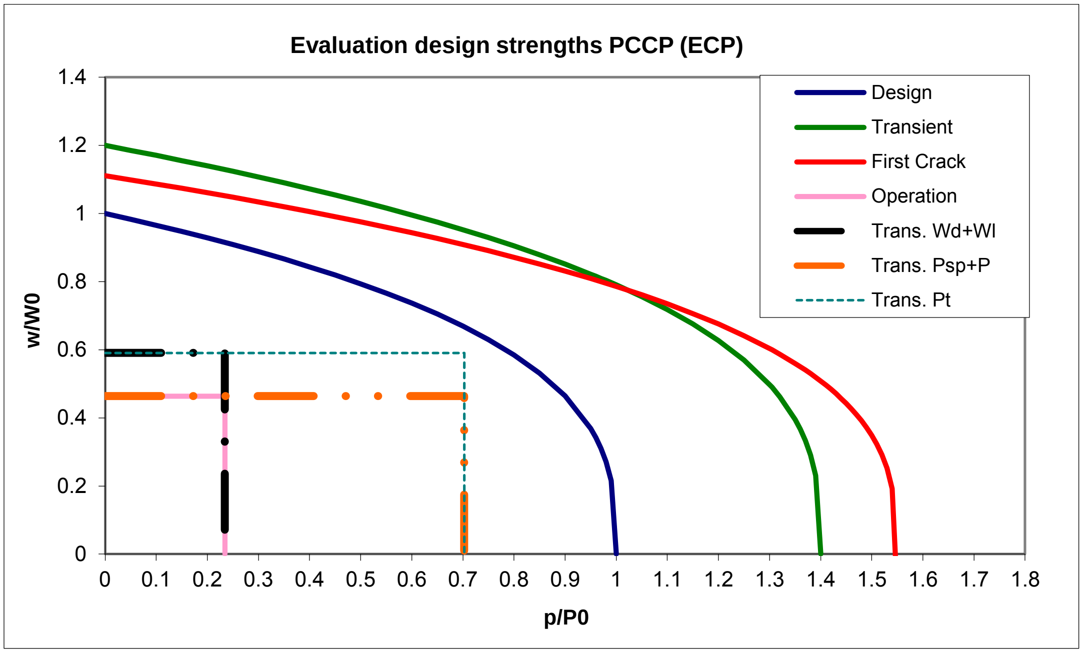


Figure 4.2. AWWA C301 Appendix A design curve for 60-inch embedded cylinder PCCP.

4.3.2 AWWA C304 and Three-Dimensional Finite Element Modeling

Initially, a structural analysis is made on the pipe design based on AWWA C304 assuming all wires are intact. AWWA C304 is a more rigorous analysis method than what was used by the industry in the 1970's. Analyses based on the current AWWA C304 Design Standard concluded that the 48-inch was operating within its design limits. However, based on the available contract documents and operating conditions, the 60 and 72-inch mains were found to be operating beyond their design limitations. Serviceability criteria governing the core to cylinder radial tension were not satisfied. In theory, the 60 and 72-inch designs experience micro-cracking in the concrete core under the operating plus surge conditions with or without the presence of broken wire wraps. It should be noted that pressure transients within the 60-inch supply main have been recorded at 15 psi with very small transient pressure fluctuations. It is recommended that the same efforts to record transient pressures be carried out on the 72-inch main. If operational and surge conditions do not tend to fluctuate beyond the acceptable limits, the risk associated with this structural design flaw should be minimal. External forensic testing on the 60 and 72-inch pipe designs is important as it may further support the theory behind AWWA 304 and finite element modeling.

The condition of the PCCP is classified into four limit states called micro-cracking, visible cracking, yield and ultimate strength. The actual wire break damage required to reach these conditions varies based on the pipe design, operational history and environmental conditions.

The model takes into consideration the expected loading conditions on a pipe section, the design variables, and estimated wire break damage to evaluate the state of stress and strain in the various pipe components and therefore the risk of failure. The risk of failure was used to form the basis of the recommendations to safely manage the subject mains. The risk evaluation involved the following tasks:

- Gather and review pipe plan and profile drawings, available laying schedule, design specifications, electromagnetic inspection results, working and transient pressures, depths of burial, live loads and all other relevant data.
- Calculate internal and external loads on the pipe, and based on AWWA C304 the performance of the pipe assuming no wire breaks.
- Using FEA, develop performance curves for distressed pipe designs to develop plots that identify for a given pressure the level of wire break damage at which a pipe section will breach serviceability, yield, and strength limit states for varying effective number of broken wire wraps.
- Determine repair priorities of all distressed pipe sections based on the risk curves developed, the maximum expected pressures and the results of the electromagnetic inspection.
- Develop recommendations regarding rehabilitation and future monitoring of the pipeline.

The following documents were reviewed and/or referenced in this report:

- Plan and profile views of the subject transmission mains along with available contract laying schedules and specifications.

This risk analysis evaluates the impact of a growing number of broken prestressing wire wraps on the performance of the pipe and the corresponding risk of failure as a result of this damage. Failure risk is expressed in terms of the Limit States as it relates to serviceability, yield, and strength of the pipe with broken prestressing wire wraps. Openaka considers both micro-cracking and visible cracking limits. Micro-cracking limit state is based on the onset of cracking in the inner core or mortar coating. It is further defined as the 0.001-inch thick crack at 12 inches in length. The visible cracking state is defined as cracking greater than 0.002 inches thick and 12 inches in length. The yield limit state is based on structural cracking of the core that exposes the cylinder to corrosion and an increase in wire stress adjacent to the broken wire wraps achieving the wire yield stress (Note: The AWWA C304 Yield Limit State is the gross wrapping stress of the wire, not the yield). The strength limit state is based on the wire ultimate strength and cylinder yield stress (Note: The AWWA C304 Strength Limit State is based on the wire yield stress, not its ultimate strength). Based on this analysis, plots were generated that show the above Limit States in terms of number of broken contiguous wire wraps and applied internal pressure for a given external load. An example of these plots can be seen in Figure 2.6. The remaining plots for all three mains can be found in Appendix F of this report.

The determination to replace an individual pipe section should be made using the Operational + Surge Pressure condition on the FEA Curve. When the number of wire breaks is determined to reach the lower threshold of the Yield Limit wire break range, Openaka recommends replacement of a pipe section. Once the wire breaks on a pipe section reaches the Yield Limit State, a pipe section may experience a higher rate of wire break damage until it reaches the Strength Limit State. Reaching the Strength Limit does not necessarily indicate a failure. Multiple pipe sections within the transmission mains either were found to have the full length of the pipe with wire break damage or very large electromagnetic anomalies indicating significant wire break damage. Structural analysis and external forensic reporting identified that a pipe cannot retain its capacity to withstand the internal pressure based on the strength of the steel cylinder alone.

Part of the pipeline evaluation and condition assessment is to evaluate risk of PCCP structural failure due to reduced structural capacity as a result of wire break damage and concrete deterioration. The prestressing wire is a principal structural component of PCCP and each individual class of PCCP installed in a particular pipeline is designed specifically for the maximum hydraulic operating pressure and soil covers expected along the route. Thus, any amount of wire break damage poses some level of risk to the pipeline and should be carefully evaluated. In an effort to quantify risk, a structural analysis and risk evaluation was performed.

A number of pipes have distress across the length of the pipe and require immediate rehabilitation or replacement. To determine the risk of failure, Openaka made a conservative assumption based on the estimated total number of broken wire wraps that all broken wire wraps are consecutive and located in the middle of the pipe. The actual pipe condition and number and distribution of broken wire wraps should be verified by external inspection and testing. The risk of failure should be re-evaluated based on the results of external inspection.

The performance curves in Appendix F were used to determine the repair priorities based on the estimated electromagnetic wire break damage and the reported operational pressure plus surge pressure.

4.4 Remaining Useful Service Life

This section discusses the remaining useful life of the transmission mains. Based on the results of Pure Technologies' inspections, each pipe section typically can be grouped into one of three categories:

- Incipient Failure. This category refers to pipes near failure and those pipes that exhibit electromagnetic signals consistent with more than the estimate required to generate a risk of failure. Multiple pipes with large electromagnetic anomalies were found in this category.

- Moderate Level of Distress. This category refers to those pipes that demonstrated an electromagnetic anomaly consistent with minimal wire breaks. This category includes all pipes identified to have electromagnetic anomalies below the yield limit state.

- No Distress. This category refers to pipes that had no evidence of a loss of prestressing or wire break damage based on the visual and sounding inspection and the electromagnetic testing.

When evaluating the remaining useful life of a pipe, an estimate must be made on the time for distress to increase from the present estimates of wire break damage to the range that could create an undesirable level of risk. The remaining useful life of a pipe is highly dependent on this rate of wire activity. Therefore, the remaining useful service life cannot be effectively determined without either a follow-up inspection or the use of acoustic monitoring to record the ongoing rate of deterioration. Tables of the distressed pipes, their corresponding distress category, are contained in Appendix G of this report.

5. Conclusions and Recommendations

5.1. Conclusions

48-inch SW Well Field Supply Main

Pure Technologies' evaluation of the 48-inch supply main concludes that:

- No leaks were detected within the main.
- Of the 1,228 pipes electromagnetically inspected, there were a total of two (2) distressed pipes that have broken prestressing wire wraps, ranging from five (5) to ten (10) wire breaks.
- Pipe 715 at Station 123+32was found with an anomalous signal that does not resemble characteristics of wire breaks. The signal shift could be caused by an undocumented feature or a property change. Pure Technologies will require documentation denoting these changes to conclusively evaluate these signals.
- Structural analysis and finite element modeling of the 48-inch pipe design conclude that the main is operating within its design limitations.
- Overall, based on the utilized inspection methods, the 48-inch SW Well Field Supply Main is in a satisfactory serviceable condition.

60-inch SW Well Field Supply Main

Pure Technologies' evaluation of the 60-inch supply main concludes that:

- No leaks were detected within the main.
- Of the 954 pipes inspected, there were a total of 21 distressed pipes that have broken prestressing wires, ranging from five (5) to 25 wire breaks, two (2) of which represent distress across their entire length.
- Structural analysis and finite element modeling of the 60-inch pipe design determined that the pipe was designed within the limits of the AWWA C301 standard in place at the time of manufacture; however, it failed to meet all of the Serviceability Limit State criteria as set forth by the current AWWA C304 Design Standard. Under normal operating plus surge conditions, the radial tension stress between the concrete core and steel cylinder exceeds the amount necessary to initiate micro-cracking in the core. Recent transient pressure data supplied by WASD has recorded the normal operating pressure at 15 psi. Transient pressure fluctuations have been shown to be minimal which minimizes the risk associated with the structural design limitations. It should be noted that the transient pressure data supplied was sampled over a six day time period.
- During the external forensic evaluation of Pipe 3423, brittle wire fractures were observed, indicating a severe degree of hydrogen embrittlement sensitivity. Based on the field measurements, the manufacturer's design specification and electromagnetic estimates of the number and location of broken prestressing wire wraps were accurate.
- Overall, the 60-inch SW Well Field Supply Main is in satisfactory condition.

72-inch SW 64th Street Transmission Main

Pure Technologies' evaluation of the 72-inch transmission main concludes that:

- A leak detection survey of the 72-inch main is still required.
- Of the 132 pipes inspected, there were a total of 6 distressed pipes that have broken prestressing wires. Two (2) were identified with broken wire wraps ranging from five (5) to 30. The remaining four (4) pipes contained damage that spanned their entire lengths.
- Structural analysis and finite element modeling of the 72-inch pipe design determined that the pipe was designed within the limits of the AWWA C301 standard in place at the time of manufacture; however, it failed to meet all of the Serviceability Limit State criteria as set forth by the current AWWA C304 Design Standard. Under normal operating plus surge conditions, the radial tension stress between the concrete core and steel cylinder exceeds the amount necessary to initiate micro-cracking in the core. Transient pressure data is required to determine the extent of this structural limitation and its impact on the remaining distressed pipes.
- Overall, the 72-inch SW 64th Street Transmission Main is in a satisfactory serviceable condition. However, further pressure analysis and forensic testing is required to completely understand the nature of operating the main under the current structural design.

5.2. Recommendations

WASD has already begun rehabilitation and replacement efforts to mitigate the risk associated with Pipes 4213, 4210, and 3423 within the 60-inch SW Well Field Supply Main; and Pipes 1829, 1846, 1835, and 1788 within the 72-inch SW 64th Street Transmission Main.

Recommendations for the long term management of the three subject mains were developed as a result of a comprehensive inspection, engineering analysis, and condition assessment of each pipe section within each of the three mains:

- The initial inspection program establishes a baseline condition of each transmission main. In order to gather data on the rate of deterioration of the asset, it is necessary to conduct periodic inspections or develop an active monitoring of the mains. To safely manage the assets and minimize the risk of future failures, WASD should take the following actions:

  1. Rehabilitate or replace seven (7) pipes, three (3) pipes from the 60-inch SW Well Field Supply Main along with four (4) pipes from the 72-inch SW 64th Street Transmission Main, that were found to be in a state of incipient failure, prior to returning the two transmission mains to service. As discussed above, WASD has already initiated rehabilitation efforts to mitigate the risk of these seven (7) pipe sections through internal carbon fiber reinforcement or replacement.

  2. Based on the inspection and structural evaluation of the subject transmission mains, a substantial risk of failure persists if replacement or rehabilitation of the above mentioned seven (7) pipes is not completed.

  3. Pipe 1847 from the 72-inch 64th Street Transmission Main was categorized with a moderate level of distress, containing 30 broken wire wraps. Finite element modeling of the 72-inch embedded pipe design calculated that the Yield Limit State will be reached when a pipe has experienced 55 contiguous broken wire wraps at an operational pressure of 75 psi, and 37 contiguous broken wire wraps during a surge

event totaling 115 psi. Openaka recommends that the risk associated with any particular pipe section should be mitigated when the total number of broken wire wraps places it at or above the Yield Limit State. It should be noted that Pipe 1847 contains an air release valve, centered within the broken wire zone. Openaka does not recommend rehabilitation but suggests future monitoring of Pipe 1847. If wire break activity has increased on Pipe 1847, it will need to be rehabilitated at that time.

4. Pipeline Management: The remaining pipe sections categorized with low levels of distress are not recommended for repair at this time. The rate of wire break activity can vary significantly depending on a number of variables. As a result, and since these pipelines are a critical asset with a high consequence of failure, it is recommended that WASD implement procedures to proactively manage the transmission main system via acoustic monitoring. An acoustic monitoring system will detect and report wire breaks as they occur in near real time. This information is combined with the electromagnetic inspection data to allow WASD to analyze the condition of the mains (i.e., the number of broken wire wraps on each pipe section). This is the best available option to minimize the risk of future pipeline failure combined with proactive rehabilitations. If an acoustic monitoring system is not implemented, Pure Technologies recommends re-inspection of the subject transmission mains within 3 years to monitor distress rates of growth and to identify additional pipes of concern.

5. Validation and Forensic Investigation: If any of the additional high priority pipe sections are located in areas where excavation is practical, it is recommended that a validation and forensic evaluation be performed while the pipe is out of service. This would involve excavating the pipeline and performing a detailed investigation of the pipe to confirm the extent of wire break damage. In addition, the groundwater, soil, and pipe constituents should be sampled and analyzed. This work should be carried out to meet two objectives:

   Validation: There are several variables that affect the accuracy of electromagnetic inspection. Validation compares the predicted level of wire break damage to the actual numbers of wire wraps to evaluate these variables. If necessary, the validation is used to adjust the electromagnetic results.

   Deterioration Mechanism: By examining the pipe and sampling the various components that contribute to the longevity of the pipeline, a determination can be made as to why a pipe section is experiencing accelerated deterioration. This information combined with the inspection information in this report, will enable WASD to determine how best to manage the subject mains to minimize the likelihood of future pipeline failure.

More specifically, as in the 60-inch forensic evaluation of Pipe 3423, Pure recommends examination and testing of the concrete core within the 72-inch SW 64th Street Transmission Main. In addition to the concrete core testing, measurements will be taken that compare wire spacing, wraps per foot, mortar thickness, steel cylinder thickness etc. The findings would then be compared to the original design specification and subsequent structural analysis results, which determined that the resultant tension in the concrete core during operation is greater than that required to initiate micro-cracking in the core. External destructive and non-destructive techniques will provide Pure and WASD a better understanding of the current condition of the 72-inch main and its future management strategies. External evaluation methods should be implemented wherever applicable among all of WASD's mains.

6. If external testing of the 72-inch main is not available, Pure recommends entering the pipeline while it is out of service to perform an internal visual and sounding inspection within the available limits surrounding the high priority distressed pipes. Cracking in the concrete core and delaminations due to broken prestressing wire wraps can be documented and studied. Ultimately, internal inspection, coupled with external evaluation, will provide Pure and WASD with the best understanding of the current condition of the 72-inch main.

7. Pressure: The structural evaluation assumed an operating pressure plus surge totaling 60 psi within the 48 and 60-inch SW Well Field Supply Mains, and 115 psi within the 72-inch 64th Street Transmission Main. In regards to the 48-inch supply main, the internal operating plus surge pressure of 60 psi is theoretically below the level required to cause a failure of the steel cylinder, without the presence of prestressing wires. Due to potential deterioration and reduction in structural capacity of the steel, WASD should not rely on the structural capacity of the steel cylinder alone to support the internal operating pressure within this main. However, in the 60-inch supply main an operating plus surge pressure totaling 60 psi is greater than that required to cause yielding of the PCCP when under the influence of any amount of broken prestressing wire wraps. Recent SCADA data received from WASD (August 3-9, 2011) shows a steady operating pressure of 15 psi with minimal transient pressure fluctuations. WASD should be able to safely manage the structural capabilities of the 60-inch main if the operating pressures remain consistent at 15 psi. It is recommended that surge events within the 60-inch supply main be managed if they exceed 30 psi. Pressure monitoring within each of the subject mains is recommended in order to understand the effects of transient pressures on PCCP with broken prestressing wire wraps.

8. Leak detection surveys should be performed within the subject mains in three years to determine if joint leaks have developed within the subject mains. Joint leaks in PCCP are often precursors to failures and early detection can prevent future pipe ruptures.

- If the above mentioned recommendations are followed, the probability of failure within the next five years is low, and the remaining useful service life of the mains may be extended. A more definitive estimate can be provided after a follow-up inspection is conducted. This inspection will provide data to understand the rate of deterioration, allowing a more qualified calculation of the remaining useful life of the pipelines. In addition, the deterioration rates will allow WASD to effectively manage the risk of potential failure in the future.

Pure Technologies recommends that WASD be proactive to maintain a low risk of failure into the future. Corrosion could develop over time, due to environmental conditions, which would increase the probability of failure. Examples of environmental conditions that facilitate corrosion include the presence of high ground water table, groundwater with high concentrations of CO_2, and high concentration levels of chloride ions in soils near the transmission main. A soil environmental study is not recommended at this time due to the lack of damage consistent with corrosive soils on the transmission main. Recommendations for a soil environmental study should be made at the completion of the next condition assessment.

References

1- American Water Works Association Research Foundation, Failure of Prestressed Concrete Cylinder Pipe, Denver, Colorado: AWWA; 2007.

2- American Water Works Association, AWWA C304 Standard for Design of Prestressed Concrete Cylinder Pipe, Denver, Colorado: AWWA; 2007.

3- American Water Works Association, AWWA C 301 Standard for Prestressed Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids, Denver, Colorado: AWWA; 1979.

4- Interpace, Lock Joint Concrete Pressure Pipe, Engineering Manual. Cherry Hill: Interpace; 1973.

5- American Concrete Pipe Association, Concrete Pipe Design Manual, Vienna: ACPA; 2007.

6- Villalobos J.L., Effects of Prestressed Concrete Pipe in a High Chloride Environment after 19 Years of Service, Pipelines in the Constructed Environment, ASCE, Reston, VA, 1998, pp. 575-583.

7- Price R.E., Lewis R.A., and Erlin B., Effects of Environment on the Durability of Prestressed Concrete Cylinder Pipe, Pipelines in the Constructed Environment, ASCE, Reston, VA, 1998, pp. 584-593.

8- Walsh T.L., Hodge D.S., Overcoming the Challenges of Replacing 20 km of Defective 1524 mm Diameter PCCP, Pipelines in the Constructed Environment, ASCE, Reston, VA, 1998, pp. 602-611.

9- Knowles W.L.C., Failure of Prestressed Concrete Embedded Cylinder Pipe, Design and Installation, Kenneth Kienow ed., ASCE, NY, 1990, pp. 434-441.

10- Galleher J.J., Stift M.T., Internal Inspection and Database Development of PCCP, Pipelines in the Constructed Environment, ASCE, Reston, VA, 1998, pp. 721-730.

11- Ojdrovic R.P., Zarghamee M.S., Hegar J.R., and Westman T., Condition Assessment of a PCCP Line Accessible from Outside Only, Pipelines 2001-Advances in Pipeline Engineering & Construction, Joseph Castronov ed., ASCE, Reston, VA (CD-ROM) ,2001.

12- Parks R.R., Drager J.K. and Ojdrovic R.P., Condition Assessment and Rehabilitation of the Windy Gap Pipeline – An Owner's Perspective, Pipelines 2001-Advances in Pipeline Engineering & Construction, Joseph Castronov ed., ASCE, Reston, VA (CD-ROM), 2001.

13- Price R.E., The Investigation Cause and Prevention of PCCP Failures, Proceeding AWWA Annual Conference, 1990, pp. 663-681.

APPENDIX A

Pure Technologies' Leak Detection Reports

APPENDIX B

Pure Technologies' Electromagnetic Inspection Report

APPENDIX C

CMC Petrographic Examination

APPENDIX D

Lewis Engineering Report – Metallurgical Testing

APPENDIX E

SOR Laboratories, Inc. – Concrete Compressive Strength

APPENDIX F

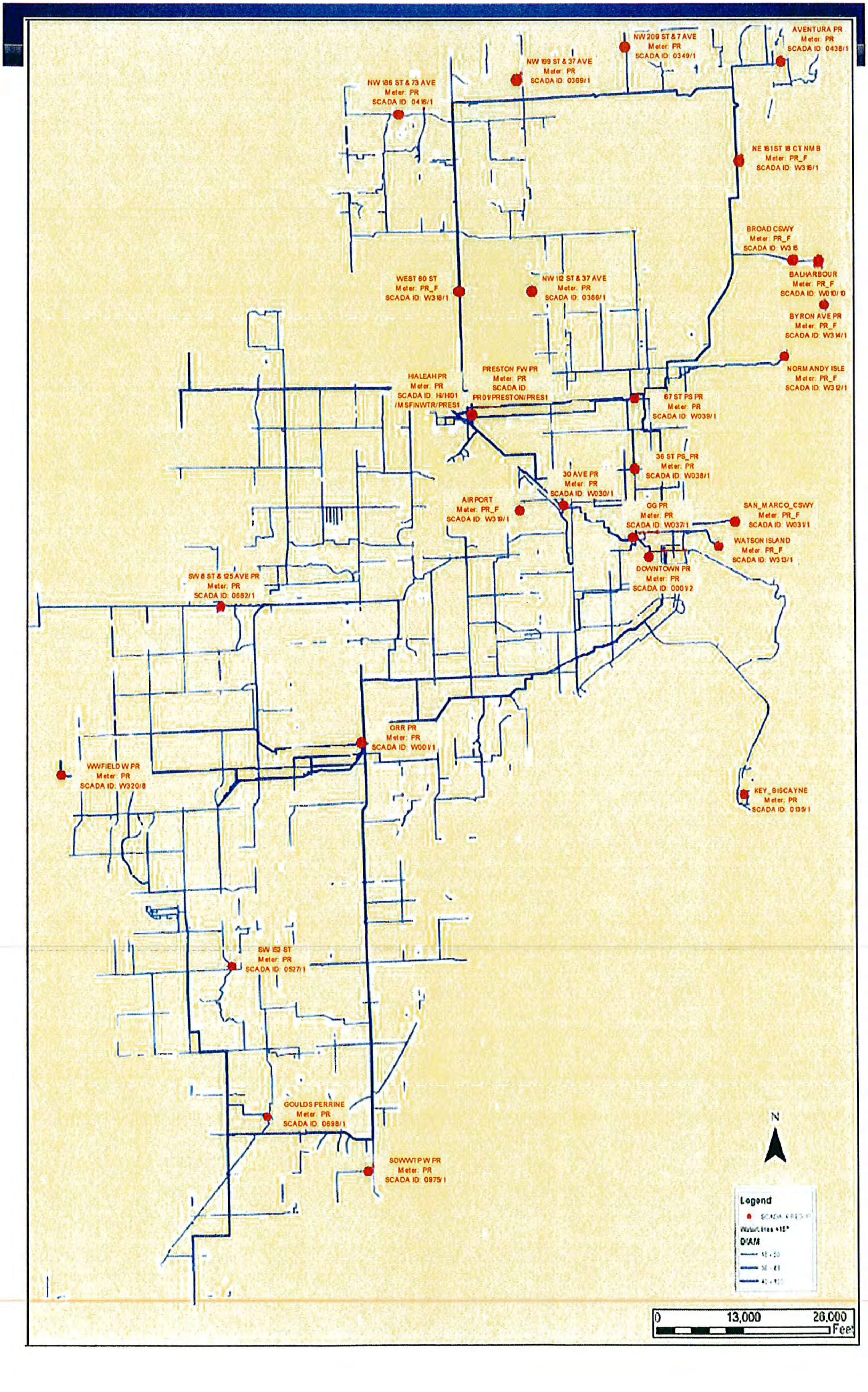
Structural Analysis/FEA Modeling Results

APPENDIX G

Tables of Distressed Pipes

Appendix D

Distribution System Pressure Monitoring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SCADA ID: 0416/1
NE 161 ST 18 CT NMB
Meter: PR_F
SCADA ID: W316/1
BROAD CSWY
Meter: PR_F
SCADA ID: W315
BALHARBOUR
Meter: PR_F
SCADA ID: W010/10
WEST 60 ST
Meter: PR_F
SCADA ID: W318/1
NW 12 ST & 37 AVE
Meter: PR
SCADA ID: 0386/1
BYRON AVE PR
Meter: PR_F
SCADA ID: W314/1
NORMANDY ISLE
Meter: PR_F
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AIRPORT
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GG PR
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SAN_MARCO_CSWY
Meter: PR_F
SCADA ID: W031/1
WATSON ISLAND
Meter: PR_F
SCADA ID: W313/1
DOWNTOWN PR
Meter: PR
SCADA ID: 0001/2
SW 8 ST & 125 AVE PR
Meter: PR
SCADA ID: 0682/1
ORR PR
Meter: PR
SCADA ID: W001/1
WWFIELD W PR
Meter: PR
SCADA ID: W320/8
KEY_BISCAYNE
Meter: PR
SCADA ID: 0135/1
SW 152 ST
Meter: PR
SCADA ID: 0527/1
GOULDS PERRINE
Meter: PR
SCADA ID: 0698/1
SDWWTP W PR
Meter: PR
SCADA ID: 0975/1
N
Legend
DIAM
0
13,000
26,000
Feet

Annual Average Pressure (psi)

WTP	
A. Orr	69.85
Preston	70.46
Hialeah	72.25
AVG	**70.9**
Median	**70.5**

Middle	
67 ST RPS	62.86
36 St RPS	61.63
GG	65.17
30 Ave	62.94
Downtown	63.23
W60 St	56.66
NW 112&37 Ave	63.77
Airport	61.09
SW8&125	63.4
SW152St	56.42
	61.7
	62.9

Far	
Key B	58.97
NW209St&7Ave	57.89
NW199St&37Crt	57.23
NW186St&73Ave	56.09
Aventura	54.36
Goulds P	
SDWWTP	54.45
Bal H	60.13
San Marco	56.96
Normandy I	52.92
Watson I	62.35
Broad Cswy	65.61
NE 161 St	58.7
	58.0
	57.6

Combined Average **63.5**

Annual Average Max Pressure (psi)

WTP	
A. Orr	72.81
Preston	73.59
Hialeah	75.51
AVG	**74.0**
Median	**73.6**

Middle	
67 ST RPS	65.71
36 St RPS	64.55
GG	67.88
30 Ave	66.27
Downtown	65.95
W60 St	59.41
NW 112&37 Ave	66.92
Airport	64.24
SW8&125	66.4
SW152St	59.73
	64.7
	65.8

Far	
Key B	62.28
NW209St&7Ave	61.12
NW199St&37Crt	60.39
NW186St&73Ave	59.22
Aventura	57.39
Goulds P	
SDWWTP	57.16
Bal H	63.3
San Marco	60.09
Normandy I	55.73
Watson I	65.47
Broad Cswy	68.8
NE 161 St	61.68
	61.1
	60.8

Combined Average **66.6**