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# Completing the Greater Boston Metropolitan Water System

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## Abstract

The Massachusetts Water Resources Authority (MWRA) currently provides wholesale water and wastewater services to over 3.1 million customers in 61 communities in eastern and central Massachusetts with most service communities located in the Boston area. The Quabbin Reservoir and Wachusett Reservoirs, which are the main water supply sources, are located 65 and 35 miles west of Boston, respectively. Plans were developed in the 1930's to provide for a redundant water system for the Boston area; however, the outbreak of WWII caused those plans to be postponed. A redundant water transmission system exists for approximately 25 miles from the Wachusett Reservoir to the beginning of existing Metropolitan Tunnel System in Weston with the Boston area remaining without redundancy.

Work today is underway to complete the Great Metropolitan Water System with a combination of pipe, tunnel and storage projects. A number of these projects are complete or currently underway. An integral part of completing the water system is the planned Metropolitan Water Tunnel Program which is proposed to consist of approximately 14.5 miles of 10-ft internal diameter deep rock tunnel at an estimated cost of approximately $1.8 billion.

This paper presents a historical perspective of water supply redundancy for the Boston area including plans originating in the 1930's, redundancy projects completed and currently underway and the Metropolitan Water Tunnel Program.

Keywords: water, redundancy, tunnel, transmission

## 1. Introduction

Reliable delivery of water is critical to protecting public health, providing sanitation, fire protection and is necessary for a viable economy. Redundancy is important in achieving a high degree of reliability for a water system. One important way that redundancy achieves this is by allowing major equipment, pipelines, and appurtenant structures to be taken offline for regular inspection and rehabilitation. Redundancy is reflected in different ways in different circumstances but generally, it means eliminating or managing 'single points of failure' within a system. Depending on the configuration of a water system, different means of providing redundancy or creating operational flexibility allows a utility to respond to emergencies or unforeseen conditions. For example, for utilities like MWRA, where there is a single water source and treatment facility that feeds the metropolitan Boston area, redundant transmission mains are critically important. Intake and treatment systems are designed following an 'N+1' philosophy to limit the impact of equipment failures on the ability to continue to deliver water. The 'N+1' strategy has a long history in waterworks and is now mandated in Department of Environmental Protection design guidelines. It provides the required number of pieces of equipment (for example chemical feed pumps) to meet the design maximum output of the facility with any (or in case of varying size equipment – the largest) piece of equipment out of service.

### *1.1 Water System Redundancy Is Not A New Idea*

Examples of redundancy principles in our metropolitan water system are sprinkled throughout the history of our great water system. In the late 1800s there were two basins at the Chestnut Hill reservoir (the former Lawrence Basin, now the site of Boston College's Alumni Stadium and Bradley Basin the sole remaining reservoir – see 1949 photograph in Figure 1 showing the two basins with Lawrence Basin in foreground, Shaft 7 construction and the Chestnut Hill pump station in the background); one to settle water from the Cochituate Aqueduct and the other the Sudbury Aqueduct but both somewhat interchangeable. At the outlet of the pump station at Chestnut Hill two (east and west) supply lines carried water to Spot Pond. There were initially two Weston Aqueduct supply lines for the Boston low service system; each taking a different route. The Cordaville pipeline was built in 1928 to bring water in from the south Sudbury (Ashland and Hopkinton) reservoirs while the Quabbin reservoir was being planned and constructed.

The Quabbin intake was constructed with two independent intake lines, one used for releases to the Swift River and the other used decades later for the Chicopee Valley Aqueduct. The Hultman Aqueduct was completed in 1940 with plans and infrastructure left behind for a second barrel. This 1940 photo in Figure 2 shows concrete placement for a future aqueduct connection at Shaft 4 of the Hultman Aqueduct. The onset of World War II prevented completion of the second pipeline. The Chicopee Valley Aqueduct was built on one side of its easement to make room for a second future barrel.

The MWRA's metropolitan distribution system has many examples of redundant pipelines and multiple community connections. The Northern Extra high service area has two pump stations to serve it (Brattle Court constructed in 1907 and Spring Street constructed in 1958). Similarly, the Southern Extra High has Hyde Park (1912) and Newton Street (1954) pump stations. The practice of having parallel pump stations operating in each service area allows facilities to be taken off line for maintenance and rehabilitation and also allows service to continue in the event of a more significant equipment failure. In 1994, a catastrophic pipeline failure shut down the Spring Street Pump Station and the system was able to shift to use of the Brattle Court Pump Station, avoiding major system disruptions to Arlington, Bedford, Belmont, Lexington, Waltham and Winchester. All of the metropolitan pump stations were designed with N+1 pumps and each has emergency backup power supply or redundant hydraulic supply (pressure reducing valves from a higher service area) to supply water in the event of a power loss.

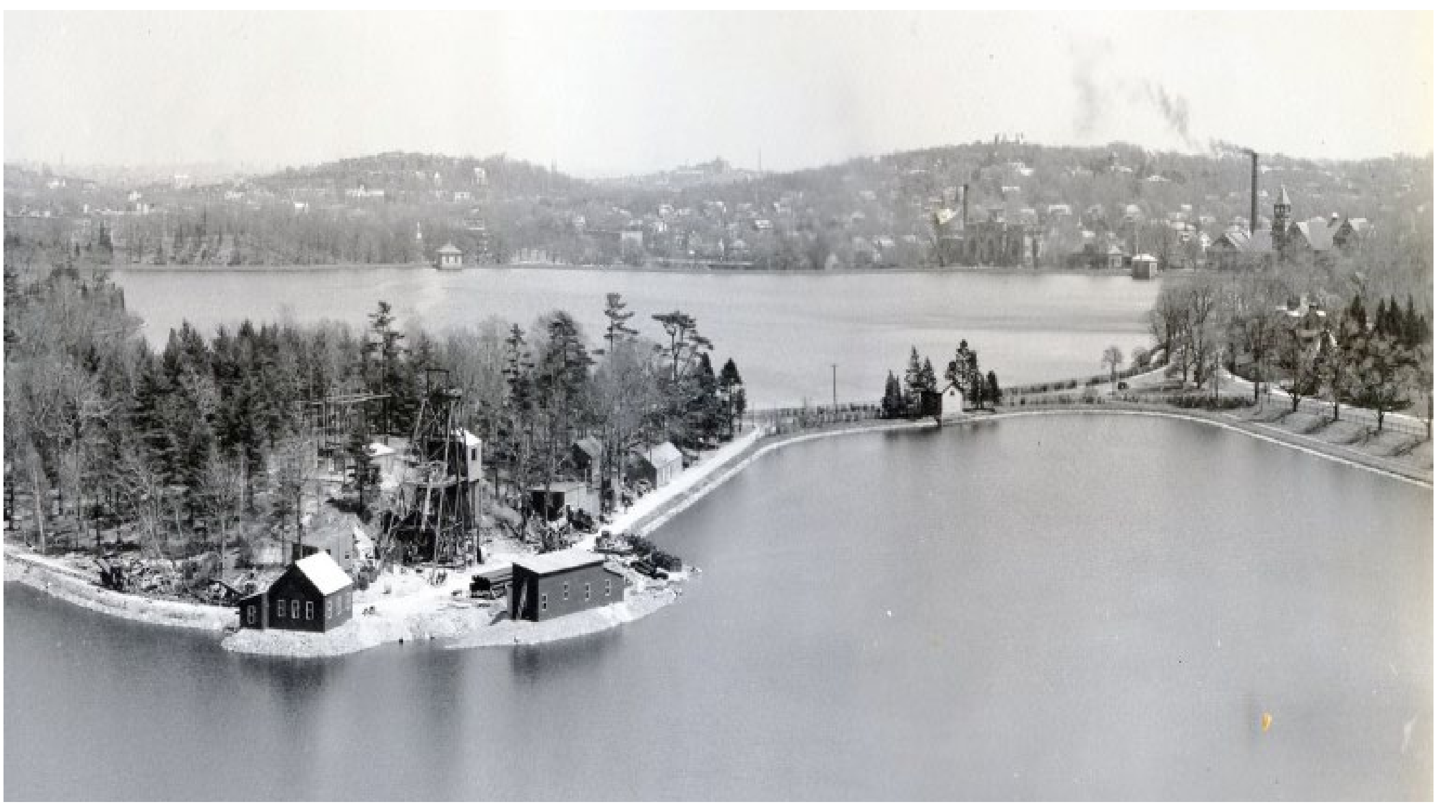

**Figure 1. Lawrence and Bradley Basins of the Chestnut Hill Reservoir (MWRA collection)**

 

**Figure 2. Future aqueduct connection at Shaft 4 of Hultman Aqueduct (MWRA collection).**

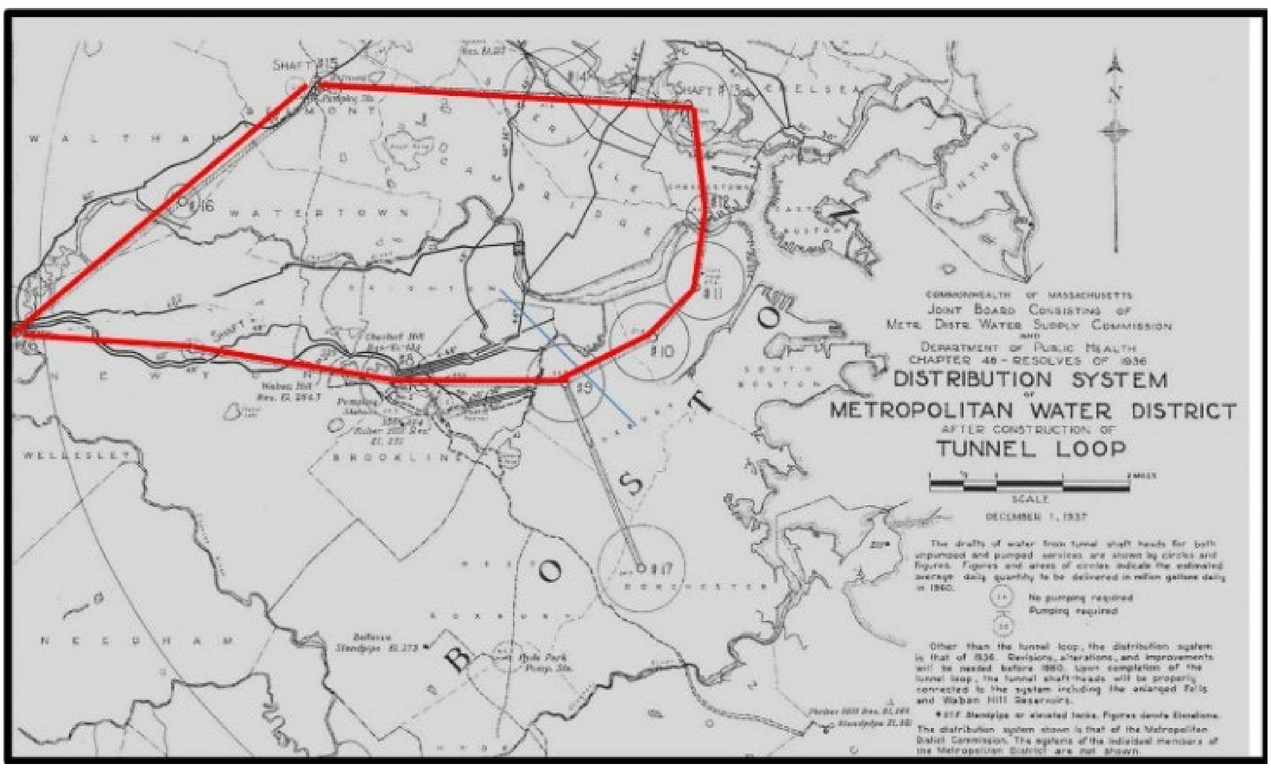


**Figure 3. Proposed Metropolitan Water District Tunnel Loop plans, the red line highlights the proposed tunnel loop (MWRA collection).**

 

The original plan for a looped Metropolitan Tunnel system was developed in 1936 as shown in the plan in Figure 3. Some of the spokes of the system were constructed; the City Tunnel (1950), City Tunnel Extension (1963) and the Dorchester Tunnel (1976) which all come together at Chestnut Hill. However, the proposed tunnel loop was never completed.

### *1.2.1 MWRA Track Record*

Since MWRA's inception, there has been an ongoing effort to improve water system operation and reliability through the MWRA capital improvement program and Master Plan process. Many of the projects that have been completed, that are underway, or are proposed provide an improvement in system redundancy in part, if not in total; eliminating single points of failure, preserving the viability of back-up systems, and preventing further loss of redundancy.

Probably the most important accomplishments in terms of elimination of single points of failure of the water transmission system is construction of the MetroWest Water Supply Tunnel, the Hultman Aqueduct interconnections project, and construction of the Wachusett Aqueduct Pump Station. After decades of planning, design and construction the tunnel came on line in November, 2003. It now provides a second means of water conveyance from the John J. Carroll Water Treatment Plant to the Norumbega Covered Storage Facility and ultimately the City Tunnel and Metropolitan Tunnel distribution system.

The MetroWest Tunnel is a 17.6 mile long, 14-foot diameter deep rock tunnel (with a 12-foot diameter connection to the Loring Road Covered Storage Facility) and it was constructed to ensure that there was a redundant means of providing water to the Metropolitan area in the event of a failure along the Hultman Aqueduct. The Hultman Aqueduct was then rehabilitated after 70+ years of continuous service and interconnecting structures created to provide the ability to isolate sections of either transmission main while continuing to provide water service to the Metropolitan area. The final Hultman interconnecting mains project was completed in 2013. This photo in Figure 4 shows the new valve chamber at Shaft 5 which provides an interconnection between the MetroWest Tunnel and the rehabilitated Hultman Aqueduct.

The Cosgrove Tunnel is another critical transmission system component that brings water from Wachusett reservoir to the Carroll Water Treatment Plant. The back-up to this tunnel is the gravity Wachusett Aqueduct which can supply approximately 240 MGD of water to the service area. The aqueduct was rehabilitated in 2002 to allow connection of the treatment plant to the Cosgrove Tunnel. However, it operates at a lower grade line than the treatment plant and therefore could not provide water that meets drinking water standards without boiling and booster chlorination. Construction of a pump station at the end of the Aqueduct was completed in 2018 as the means to protect against a Cosgrove Tunnel failure. The pump station is shown in Figure 5. The facility lifts water to the treatment plant, allowing the Cosgrove Tunnel to come out of service without impacting water quality. The 240 mgd capacity allows for unrestricted supply for at least eight months during the lower demand fall/winter/spring period.

Other completed transmission and distribution redundancy projects include:

The Chestnut Hill Emergency Pump Station was constructed in 2001 to supply the Southern High and Southern Extra High service areas in an emergency by taking water from the Sudbury Aqueduct via the Chestnut Hill Reservoir or by taking water from the Low Pressure system. The 90 mgd capacity reflects the station taking non-potable water from the Chestnut Hill Reservoir. This station was instrumental to the success of MWRA's response to the break at Shaft 5 in 2010.

The Spot Pond Pump Station and Storage Tank project (shown in the photo in Figure 6) provides back-up capabilities to the Gillis pump station, similar to the back-up stations constructed in the 1950's in the Northern Extra High and Southern Extra High service areas. Gillis Pump Station supplies the Northern Intermediate High/Bear Hill service area and the Northern High

**Figure 4. Valve chamber at Shaft 5 connecting MetroWest Tunnel and Hultman Aqueduct (MWRA).**

 

Service/Fells service area. The new Spot Pond Pump Station and Storage Tank (completed 2015) provides operational flexibility for supply to the Northern Intermediate High and Fells service areas and 20 million gallons of critical storage for the Northern Low service area in the event of service interruption. The Spot Pond Pump Station is capable of drawing water from either the low service or high service zones and can pump to the high and intermediate high zones providing much needed redundancy to Gillis Pump Station.

In addition to the improvements described above to the NIH service area pumping capability, another series of crucial projects is underway to eliminate what is essentially a single pipe system and concern over the potential for a catastrophic failure of a 10,000 foot portion of this pipeline made of Prestressed Concrete Cylinder Pipe that was constructed by a particular manufacturer with a Class IV wire that has been prone to embrittlement and failure elsewhere in the country. A completed redundant pipeline 6 miles long and 36 to 48 inches in diameter now supplies the area and the fifth and final construction contract to replace the pipeline of concern is underway.

Figure 5. Wachusett Aqueduct Pump Station (MWRA 2004-2015)

Figure 6. Spot Pond Pump Station and Storage Tank project (MWRA 2004-2015)

In the Southern Extra High Service Area, pipeline Sections 77 and 88 were single spine mains serving Canton, Norwood, the Dedham-Westwood Water District and Stoughton. Although four of these communities are partially supplied and may be able, in part, to provide some level of service in the event of a pipeline leak, break or other failure, Norwood is fully supplied by MWRA. MWRA's Southern Extra High service area provides drinking water to Canton, Dedham, Norwood, Stoughton, Westwood, portions of Brookline and Milton, and the Roslindale and West Roxbury sections of Boston. This project, completed in 2020, provides redundancy for this pressure zone. The photo in Figure 7 shows masked staff turning the valve to activate the new pipeline during the height of the corona virus pandemic. Construction of the 5.4 mile 36-inch diameter water main was broken into three separate construction contracts through Boston, Dedham, and Westwood.

 

Figure 7. Masked staff activating new pipeline during corona virus pandemic (MWRA)

## 2. Remaining Transmission System Redundancy Needs / Completing the 1936 Plan:

The completed and ongoing improvements to surface piping, pump stations and storage facilities however, do not replace the need for redundancy for the Metropolitan Tunnel System (i.e., City Tunnel, City Tunnel Extension, and Dorchester Tunnel). The need for this redundancy was highlighted in May 2010 when a coupling joining two segments of 10 foot diameter pipe located between the MetroWest Tunnel and Shaft 5 ruptured resulting in a strain on system supply, the need for a major system reconfiguration and activation of back-up supplies. The incident resulted in a release of approximately 250 mgd over a period of eight hours until the break was isolated. During this time, an emergency water source was activated to maintain water supply prior to shutting down the affected pipe. While the pipe was being repaired over the following two days, the Boston metropolitan area was supplied through alternate lower capacity mains with augmentation from an emergency raw water reservoir with chlorination. The entire metropolitan service area was issued a boil water order during these two days. This boil water order affected approximately 2 million people in 30 serviced communities.

Unfortunately, this water main break occurred while the Hultman Aqueduct was off-line for long needed maintenance and repairs, otherwise a transition of supply from the MetroWest Tunnel to the Hultman would have been implemented with no interruption in service.

In 2017 the MWRA Board of Directors approved a plan to construct 2 new deep rock water tunnels to provide redundancy for the aging Metropolitan Tunnel System which, once constructed, will allow it to be taken out of service and receive much needed inspections, maintenance, and repairs.

Planning and design for the Metropolitan Water Tunnel Program, approximately 14.5 miles of deep rock pressure tunnel located within the greater Boston area, has been underway since 2018. These new tunnels along with rehabilitation of the WASM3 pipeline, will provide the much needed redundancy and complete the 1936 plans for a tunnel loop.

The Tunnel Program will connect to the Hultman Aqueduct in Weston with one tunnel extending ~4.5 miles north to Waltham, near the Belmont line where a connection to MWRA’s Weston Aqueduct Supply Main number 3 will be made and a second tunnel extending ~10 miles south/southeast to Mattapan with a connection to surface pipelines near Shaft 7C of the Dorchester Tunnel. Six smaller diameter intermediate shafts will be constructed along the tunnel alignments to allow for connections to be made to MWRA and community pump stations as well as key surface piping. Figure 8 shows the planned shaft locations as well as the Program study area that was initially evaluated.

The Tunnel Program is currently in the preliminary design phase and is targeting the start of tunnel construction in 2027.

Preliminary design involved a significant alternatives evaluation that resulted in the selected shaft sites and a preferred tunnel alignment which is summarized in the recently submitted DEIR and SDEIR for the Program. Geotechnical investigations, survey, permitting, hydraulics analysis, site layout, shaft and tunnel design, and other aspects of preliminary design are underway. An important component of the preliminary design will be the selection of how the various construction elements (shafts, tunnel, surface structures, etc.) will be packaged into construction contracts, the phasing of the construction contracts and an updated cost estimate and construction schedule. MWRA’s Capital Improvement Program currently includes $1.8B for the Tunnel Program with overall Program completion on or before 2040.

Once constructed, the Metropolitan Water Tunnel Program will complete the vision of a looped Metropolitan Tunnel system that has been almost a century in the making and at times had few

 

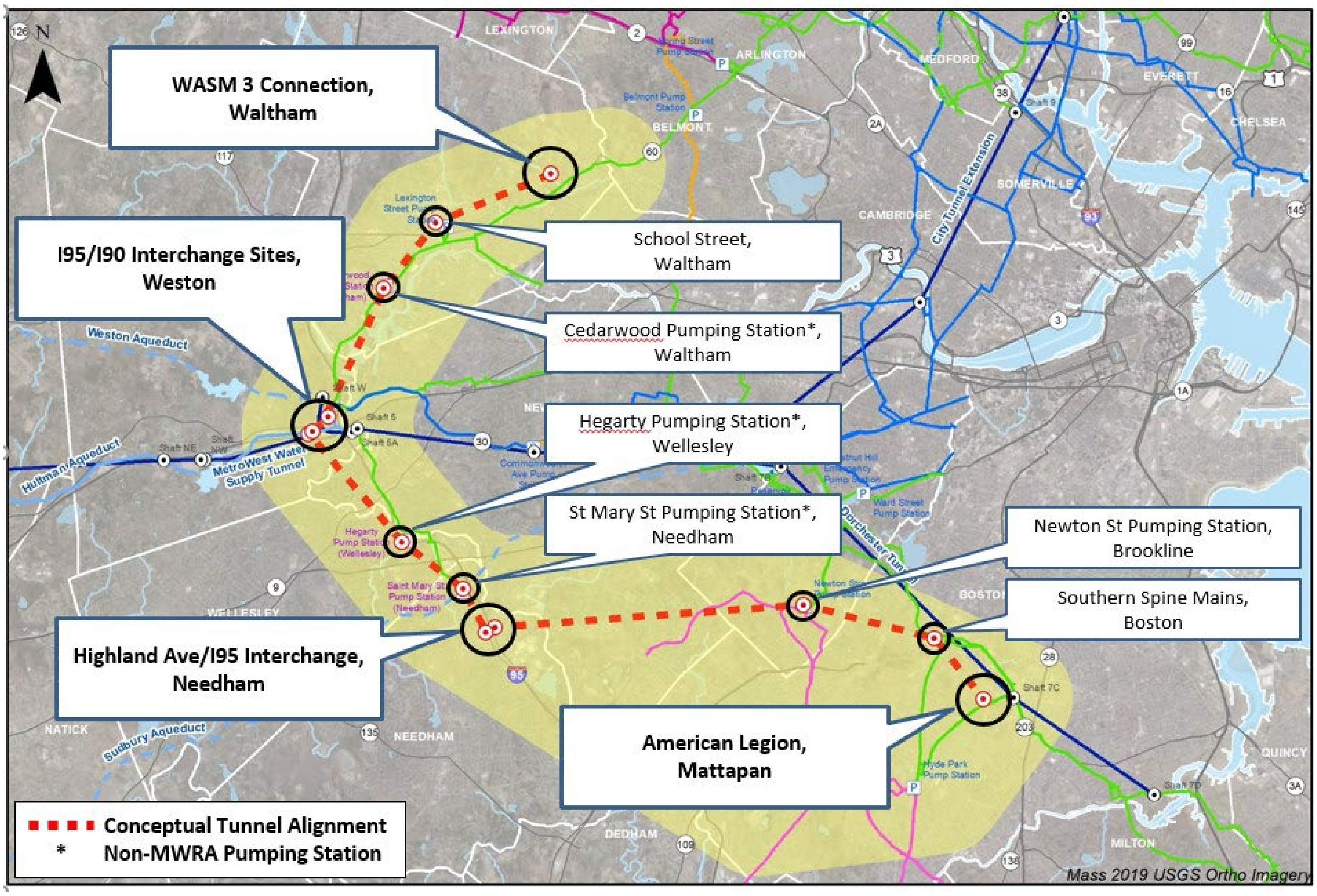


Figure 8. Proposed shaft locations and program study area of initial evaluation (MWRA 2004-2015)

champions and little support. An unfiltered water system, with a pure upland water source, strong watershed protection, gravity feed, and soon with a fully redundant transmission system; the Metropolitan Water System is truly great. In an era of water system vulnerability, the MWRA water supply and distribution system is, and will continue to be for future generations a key element of health, opportunity, and prosperity for the Boston Metropolitan area with the completion of several projects through the MWRA capital improvement program and Tunnel Programs.

## Acknowledgements

The Great Metropolitan Water System of the Boston area has been centuries in the making. Significant contributions have been made over time by various organization and individuals, too numerous to list. Their vision and determination cannot be understated. It is the foundation of our current great water system which is now in the capable hands of MWRA leadership and staff along with many consultants, contractors and suppliers. Continuation and completion of that vision is our mission; one that we eagerly pursue.

## References

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