Town of Holden, Massachusetts

Water Distribution System Master Plan

May 2006

Revised: October 2006

Final Report

CDM
One Cambridge Place, 50 Hampshire Street
Cambridge, Massachusetts 02139
tel: 617 452-6000
fax: 617 452-8000

October 26, 2006

Mr. Lawrence H. Galkowski
Director
Department of Public Works
1196 Main Street
Holden, Massachusetts 01520

Subject: Final Report
Water Distribution System Master Plan
Town of Holden, Massachusetts

Dear Mr. Galkowski:

In accordance with Work Order No. 5, Camp Dresser & McKee Inc. (CDM) is pleased to submit nine copies of the *Final Report - Water Distribution System Master Plan*. This report along with the associated mapping and distribution system model provide a valuable tool to the Town for managing and improving the distribution system to ensure a safe and reliable water system for Holden. In addition, the report outlines a prioritized list of capital improvements for implementation over the next twenty years.

Once again, we would like to thank Mr. Randy Swigor, Water and Sewer Superintendent, and Mr. Paul Majewski, Water and Sewer Foreman, for providing invaluable information and support during this study.

We appreciate the opportunity to have assisted the Town in developing this planning document and look forward to its implementation. As always, please call me at (617) 452-6532 if you have any questions or require additional information.

Very truly yours,

Andrew B. Miller, P.E.
Principal Engineer
Camp Dresser & McKee Inc.

Enclosure

cc: R. Swigor – Holden
E. Nazaretian – CDM
P. Cabral – CDM
Project Files

MJ2115f.doc

Contents

Appendices

Figures

Tables

Executive Summary

Introduction

The Town of Holden has recently completed an extensive infrastructure improvement program to its water distribution system. These improvements were necessary to achieve compliance with the federal mandated Safe Drinking Water Act (SDWA) and to ensure adequate water supply capacity for Holden well into the future. The water distribution system study has proceeded in parallel with these improvements. In fact, the study has provided the technical design basis for many of the infrastructure improvements and facility modifications implemented.

In general, the overall goals and objectives of this water distribution system master plan have been to:

1. Provide the Town of Holden with an up-to-date map of its water distribution system.

2. Develop a calibrated hydraulic model of the water distribution system for identifying system deficiencies and for analyzing the impact of changes to the system.

3. Evaluate Holden's distribution system over a 30-year planning period and develop a prioritized list of improvements needed to provide the town with safe and reliable water service.

Recommended improvements to the system are aimed at correcting existing system deficiencies, as well as potential future deficiencies. The design year has been estimated as 2030 and water demands have been projected over this planning period.

Project Scope

The following major tasks have comprised the scope of this project:

- Data Collection
- Water Quality Assessment
- Computer Model Development
- Field Testing
- Distribution System Piping Analysis
- Distribution System Storage Analysis
- Distribution System Reliability Analysis
- Development of Recommended Improvements
- Recommendation of an Annual Maintenance Program
- Cost Estimating of Recommended Improvements and Programs
- Report Preparation

Existing Distribution System

The Town of Holden's water distribution system is comprised of four groundwater wellfields, two interconnections with the City of Worcester, one emergency surface water connection, four water storage tanks, and approximately 105 miles of water mains of various types, sizes and ages. The distribution system is also divided into two major pressure zones to serve the range of elevations of the water service areas. The location of all the water system facilities are shown on the Water Distribution System Map, appended to this report.

All of the town's water is supplied from the following facilities:

- Mason Road Wellfield (Low Service System)
- Mill Street Wellfield (Low Service System)
- Quinapoxet Wellfield (Low Service System)
- Spring Street Well (High Service System)
- Brattle Street interconnection with Worcester (High Service System)
- Salisbury Street interconnection with Worcester (High Service System)
- Muschopauge Pond (High Service System - Emergency Supply Only)

All of the Town's water supply facilities are treated with sodium fluoride for fluoridation and all of the Town's groundwater supply facilities are treated with potassium hydroxide for corrosion control. The Spring Street Well can also be treated with sodium hypochlorite for disinfection, if required. Similarly, the Quinapoxet and Mill Street Wellfield treatment facility has room to install sodium hypochlorite for disinfection, if required in the future.

The town's water distribution system includes the following storage facilities:

- Highland Street Reservoir (Low Service System)
- Avery Heights Standpipe (High Service System)
- Jefferson Reservoir (High Service System)
- Chapin Road Reservoir (Super High Service System)

The Highland Street Reservoir is a reinforced concrete tank. The Avery Heights Standpipe, Jefferson Reservoir, and Chapin Road Reservoir are all welded steel water storage tanks.

Holden's distribution system also consists of approximately 105 miles of water mains, with approximately 25 miles of cast iron water mains (4 miles of which have been cleaned and cement lined), 45 miles of asbestos cement water mains and 35 miles of cement lined ductile iron water mains.

Water Consumption Projections

To determine the water system improvements required to adequately satisfy Holden's future needs, population census and water consumption data from the past 15 years were reviewed. Based on the population trend, CDM projected the average day, maximum day and peak hour water demands for the town. These projections resulted in the following water consumption estimates for the year 2030:

- Average Day Demand – 1.95 MGD
- Maximum Day Demand – 3.90 MGD
- Peak Hour Demand – 6.83 MGD

Water Distribution System Model Development

To evaluate Holden's water distribution system under estimated future 2030 conditions, a computer model of the distribution system was developed. The software used to simulate the water distribution system was WaterGEMS® Version 3.0 developed and distributed by Haestad Method, Inc. of Waterbury, Connecticut.

The data used to develop the model was provided by the Town and was based primarily on the existing water distribution system pipe schematic map. CDM conducted hydrant flow tests and C-value tests to calibrate the model to field conditions. The calibrated model was then verified by comparing model outputs to the Supervisory Control and Data Acquisition (SCADA) system data. The calibrated and validated model was then used to identify water system deficiencies.

Distribution System Evaluation Criteria

CDM evaluated Holden's piping, pumping and storage facilities to determine the adequacy of the existing water distribution system to meet future water demand conditions and provide fire protection. The water distribution system, including the recent improvements, was evaluated using the calibrated model developed for the project. The following analysis criteria were established.

System Hydraulic Analysis Criteria

The water system facilities (i.e., piping, pumping and storage facilities) were evaluated to determine the system's ability to meet minimum pressure requirements under the following demand conditions for the target year of 2030:

- Fire flow requirements during maximum day demand
- Peak hour during maximum day demand

According to the Massachusetts Department of Environmental Protection (MassDEP) 2001 Guidelines and Polices for Public Water Systems, the criteria for water main design is: "The system shall be designed to maintain a minimum pressure of 20 psi at ground level at all points in the distribution system under all operating conditions." This standard helps to avoid potential cross-connections and negative pressures (vacuum) that could occur at service connections (at high elevations) during fire flows or other significant demand events.

For this study, the desired minimum pressure during the peak hour demand period was 35 psi at ground elevation in all areas of the Town served by the water system. During a maximum day demand with a coincidental fire flow, the desired minimum pressure of 20 psi should be maintained throughout the system.

In addition, according, to the American Water Works Association (AWWA) Manual of Water Supply Practices, "Computer Modeling of Water Distribution System" (AWWA M32, Second Edition, 2005), pipes are considered potentially deficient or limiting if they are predicted to have any of the following conditions:

- Velocities greater than 5 feet per second;
- Head losses greater than 6 feet per 1,000 feet in pipes with diameters less than 16 inches;
- Head losses greater than 2 feet per 1,000 feet in pipes with diameters 16-inch and greater.

These limits were used as a general indicator of potential problems. The ultimate test of the adequacy of a water main is the pressure that is provided at the delivery point in order to meet the required Insurance Services Office (ISO) fire flow rate.

Distribution System Storage Analysis Criteria

Adequate storage is defined as the ability of the system to provide the storage volume required as summarized below:

- Equalization Storage: The total volume required to meet hourly demand, which exceeds the maximum day demand.
- Fire Protection Storage: The total volume of water required to provide fire protection.
- Emergency Storage: The volume of storage allocated in case of a power failure, pipeline break, or equipment malfunction.

Distribution System Reliability Analysis Criteria

Adequate system reliability is defined as the ability of the system to supply maximum day demand under various emergency conditions. Emergency conditions include equipment malfunctions, pipeline break, or power failure.

Distribution System Evaluation Results

Based on the analyses conducted on the existing storage, pumping and piping facilities, which include all the recent improvements, the following conclusions were made regarding the adequacy of the existing system to meet projected water system demands for 2030:

- There is adequate active storage volume in the system to meet projected future demand conditions. To improve water level operation within the Chapin Road Tank, CDM recommends an upgrade to the existing PRV located within the Chapin Road Booster Station to an electrically controlled valve, similar to the Brattle Street Interconnection Valve, and abandonment of the Chapin Road PRV located within the below ground vault. CDM also recommends that the Town perform a structural analysis of the Highland Street Storage Tank and inspect and rehabilitate steel tank coating systems of the Chapin Road Tank and Avery Heights Tank.

- There are adequate pumping facilities to supply all zones to meet projected future demands. The pumping facilities also have sufficient pumping redundancy and the system has adequate emergency storage volume to supply projected maximum day demand under various emergency conditions in all service zones, with the exception of the Morningside Development super high system and Fox Hill Development super high system. For the Morningside Development super high system, CDM recommends that the Town install a second lead pump and VFD to provide adequate redundancy at the Morgan Circle Booster Station. For the Fox Hill Development super high system, CDM recommends that the Town install a permanent fire pump at the Sycamore Drive Booster Station to provide adequate fire protection. Until a permanent fire pump is installed at the Sycamore Drive Booster Station, CDM recommends that the Town develop a fire protection plan with the Fire Department and install two hydrants located near the Chapin Road Tank access road to allow the fire department to pump water from the Chapin Road Tank super high system into the Fox Hill Development super high system. CDM also recommends that the Town purchase a portable standby generator for the Brattle Street Valve Vault in order to operate the facility fully during an emergency power failure.

- In general, Holden's water distribution system is considered hydraulically well-connected. The water distribution system, inclusive of the recent water system improvements, can meet projected future demands while maintaining a residual of 35 psi or greater throughout the system, with the exception of the very limited areas immediately surrounding the water storage tanks. As predicted by the computer model, the water distribution system is also able to provide the required fire flows under projected future demands at all ISO test locations, with the exception of Boyden Street at Woodland Road.

- Replacing the 6-inch unlined cast iron water main on Boyden Street and the 6-inch unlined cast iron water main on Woodland Road with new 8-inch cement lined ductile iron water mains would address the one deficient ISO fire flow area.

- Overall, by replacing or rehabilitating the other hydraulically deficient water mains listed in Table E-3, the Town will eventually help address the majority of water quality complaints associated with system disruptions and dirty water. In addition, the Town should work to remove all small diameter water mains, hydraulic bottlenecks in the system, and replace aging and problematic asbestos cement water mains whenever possible.

Recommendations for capital improvements to the distribution system are aimed at correcting the remaining water distribution system inadequacies detailed above and discussed below.

Recommended Improvement Program

The overall objective of these improvements is to provide adequate system flow capacity, meet pressure criteria, and improve reliability and water quality. The recommended improvements program is arranged in four categories:

- **Geographic Information System (GIS) Implementation**: – GIS implementation for the Town will provide the Water Department with more accurate water system maps and help manage the water system maintenance program.

- **Annual Maintenance Program Recommendations:** The Annual Maintenance Program Recommendations address such times as storage facility inspection programs and hydrant and valve maintenance programs. These programs should be initiated as soon as possible and extend over the long-term since proper operation and maintenance of these facilities can result in significant improvements in system hydraulics and water quality. In addition, many of these programs are now required in order to maintain compliance with the Town's Water Management Act (WMA) permit.

- **Storage and Pumping Station Capital Improvements:** Storage and Pumping Station Capital Improvements address storage and pumping station deficiencies. Storage and Pumping Station Capital Improvements will improve available storage and distribution system reliability and are therefore the highest priority improvements.

- **Piping System Capital Improvements:** Piping System Capital Improvements address piping system deficiencies identified in the hydraulic analysis. Piping System Capital Improvements will improve overall piping network reliability and water quality, and can be implemented over the long-term (see appended Water Main Rehabilitation Map).

Table E-1 provides an estimated annual allowance for the Annual Maintenance Program. Table E-2 provides estimated construction costs for Storage and Pumping Station Capital Improvements. Table E-3 provides estimated construction costs for Piping System Capital Improvements.

The estimated annual allowances and estimated construction project cost in the tables are based on current construction and engineering costs as of April 2006 and are referenced to an Engineering News Record (ENR) Construction Cost Index of 7695.

The estimated construction project cost for these capital improvements also includes an allowance of 45 percent for engineering and contingencies.

For a more detailed discussion of each of these recommendations, please see Section 7 of this report.

Table E-1
Summary of Annual Maintenance Programs

Annual Maintenance Program	*Estimated Annual Cost* [1]
Valve Maintenance Program	$30,000
Hydrant Maintenance Program	$20,000
Unidirectional Flushing Program	$15,000
Storage Tank Inspection Program	$5,000
Wellfield Redevelopment Program	$25,000
Water Conservation Program	$15,000
Unaccounted-for Water Reduction Program	
Water Audit Program [2]	-
Meter Replacement Program [3]	$50,000
Master Meter Calibration Program	$5,000
Leak Detection Program	$10,000
Total	**$175,000**

Notes:
1. Estimated annual cost only covers the cost of materials, water purchase from Worcester and/or subcontractors including contingency. Estimated annual cost does not include cost of town forces. All costs are in year 2006 dollars (ENR April 2006 = 7695).
2. No cost shown as work assumed to be performed by Town.
3. The anticipated start date of the Meter Replacement Program is 2010.

Table E-2
Summary of Storage and Pump Station Capital Improvement Program

Capital Improvement Program	*Estimated Planning Level Cost* [1]
Water Storage Tank Improvements:	
Avery Heights Standpipe Painting [2]	$375,000 - $525,000
Chapin Tank Reservoir Painting [2]	$650,000 - $850,000
Highland Street Structural Inspection	$5,000
Highland Street Structural Repairs [3]	Not Available
Water Storage Tank Operation Improvement:	
Chapin Tank Booster Station/PRV Upgrade	$75,000
Pumping Station Improvements:	
Morgan Circle Booster Station – New Lead Pump [4]	$50,000
Sycamore Drive Booster Station – Develop Fire Protection Plan and Install New Hydrants (Short-Term Solution)	$5,000
Sycamore Drive Booster Station – New Pump Skid with Fire Pump	$225,000
Supply Facility Improvement:	
Brattle Street Interconnection – Portable Standby Generator [5]	$10,000

Note:
1. The estimated planning level costs for water storage tank operation, pump station and supply facility improvements include construction, engineering and contingency. All costs are in year 2006 dollars (ENR April 2006 = 7695).
2. The tank painting costs will depend on the type of exterior surface preparation and exterior containment required. Cost does not include additional water purchase when tank(s) are off-line, if required.
3. No planning level cost can be provided until structural inspection complete.
4. The estimated planning level cost for the Morgan Circle Booster Station assumes the Town will procure the services of a factory authorized service provider for SyncroFlo (formally Liquid-trol) pump systems without the need for formal bid documents.
5. The estimated planning level cost for the Brattle Street Interconnection portable standby generator assumes the Town will purchase the portable standby generator and transfer switch directly for installation by the Town's electrician.

Table E-3
Summary of Piping System Capital Improvement Program

Location [1]	**From**	**To**	**Existing Pipe Diameter (in.)**	**Approx. Length (ft)**	**Replacement Pipe Diameter (in.)**	**Cleaning & Cement Lining**	**Estimated Planning Level Cost [2]**
Mayflower Cir.	Colonial Dr.	Colonial Dr.	6	1,000	8		$250,000
Boyden St.	Main St.	Main St.	6	1,000	8		$250,000
Woodland Rd.	Boyden St.	Highland St.	6	2,000	8		$500,000
Shrewsbury St.	Main St.	Brattle St.	10, 8	2,500/3,000		X	$850,000
Shrewsbury St.	Brattle St.	West Boylston Town Line	6	5,000	8		$1,250,000
Holden St.	Shrewsbury St.	Worcester Town Line	6	6,000	8		$1,500,000
South Main St.	Shrewsbury St.	Newell Rd.	6	6,400	8		$1,600,000
Main St.	Reservoir St.	Shrewsbury St.	10	8,500		X	$1,450,000
Bailey Rd.	Main St.	Existing 8”	6	3,000	8		$750,000
Salisbury St.	Main St.	Existing 12”	8	3,000	12		$900,000
Reservoir St.	Main St.	Existing 12”	6	1,500	12		$450,000
Doyle Rd.	Brattle St.	Worcester Town Line	6	3,000	8		$750,000
Chapel St.	Shrewsbury St.	Existing 12”	6	3,000	12		$900,000
Wachusett St.	Shrewsbury St.	End	6	1,500	8		$375,000
Lincoln Ave.	Chapel St.	End	6	1,500	8		$375,000
Highland St.	Main St.	Union St.	10, 8, 6	700/300/3,000		X	$600,000
						Total	**$12,750,000**

Note: 1. Presented in order of high to low priority
2. Estimated planning level costs include construction, engineering and contingency. All costs are in year 2006 dollars (ENR April 2006 = 7695). No allowance for legal fees, land taking or easements.

Prioritized Capital Improvement List

The following is a recommended prioritized list of improvement projects for implementation.

Table E-4
Prioritized Capital Improvement List

Capital Improvement Project	*Estimated Planning Level Cost* [1]
Highest Priority Improvements (within 5 years)	
Chapin Tank Reservoir Painting [2]	$650,000 - $850,000
Highland Street Structural Inspection	$5,000
Morgan Circle Booster Station – New Lead Pump [3]	$50,000
Sycamore Drive Booster Station – Develop Fire Protection Plan and Install New Hydrants (Short-Term Solution)	$5,000
Chapin Tank Booster Station/PRV Upgrade	$75,000
Brattle Street Interconnection – Portable Standby Generator [4]	$10,000
Mayflower Circle Water Main Replacement	$250,000
High Priority Improvements (within 10 years)	
Avery Heights Standpipe Painting [2]	$375,000 - $525,000
Boyden Street Water Main Replacement	$250,000
Woodland Road Water Main Replacement	$500,000
Shrewsbury Street Water Main Cleaning and Lining	$850,000
Shrewsbury Street Water Main Replacement	$1,250,000
Holden Street Water Main Replacement	$1,500,000
South Main Street Water Main Replacement	$1,600,000
Priority Improvements (within 20 years)	
Main Street Water Main Cleaning and Lining	$1,450,000
Bailey Road Water Main Replacement	$750,000
Salisbury Street Water Main Replacement	$900,000
Reservoir Water Main Replacement	$450,000
Doyle Road Water Main Replacement	$750,000
Chapel Street Water Main Replacement	$900,000
Wachusett Street Water Main Replacement	$375,000
Lincoln Ave Water Main Replacement	$375,000
Highland Street Water Main Cleaning and Lining	$600,000
Improvements with No Timeframe	
Highland Street Structural Repairs [5]	Not Available
Sycamore Drive Booster Station – New Pump Skid with Fire Pump (Long-Term Solution)	$225,000

Note:
1. The estimated planning level costs for water storage tank operation, pump station, supply facility and piping system improvements include construction, engineering and contingency. All costs are in year 2006 dollars (ENR April 2006 = 7695). No allowance for legal fees, land taking or easements.
2. The tank painting costs will depend on the type of exterior surface preparation and exterior containment required. Cost does not include additional water purchase when tank(s) are off-line, if required.
3. The estimated planning level cost for the Morgan Circle Booster Station assumes the Town will procure the services of a factory authorized service provider for SyncroFlo (formally Liquid-trol) pump systems without the need for formal bid documents.
4. The estimated planning level cost for the Brattle Street Interconnection portable standby generator assumes the Town will purchase the portable standby generator and transfer switch directly for installation by the Town's electrician.
5. No planning level cost can be provided until structural inspection complete.

Section 1
Introduction

1.1 Water System History

Holden's municipal water supply system began when the Town acquired the rights to construct a water supply under the provisions of the Acts of 1896, Chapter 180. This act provided the Town of Holden with the right to take water from Muschopauge Pond in Rutland by purchase or otherwise. In 1904, the Town accepted the provisions of the Act and in 1905 begin installing large diameter cast iron water mains from Muschopauge Pond into Holden Center.

Until the 1950s, Muschopauge Pond was the sole source of water for both Holden and Rutland. The serious depletion of Muschopauge Pond during dry years led the Town of Holden to have the engineering firm of Metcalf and Eddy study the existing supply and distribution system in 1949. The first 1950 Metcalf and Eddy report recommended chemical treatment of Muschopauge Pond water to control corrosion, taste and odor problems, while the second 1950 report recommended the exploration of Quinapoxet River Valley and other areas to develop groundwater supply sources. Based on these recommendations, Whitman and Howard Engineers designed the Muschopauge Pond Chemical Feed Building (constructed in 1952) and the Spring Street Well Station (constructed in 1955).

In 1953, the Town of Holden contracted Whitman and Howard to determine the storage requirements for critical conditions in Holden Center and Chaffinville. As a result of the investigation, the Town constructed the Avery Heights Standpipe, the Chaffin Elevated Tank, and the Adams Road Booster Station.

Once again in 1957, severe drought conditions caused the water level within Muschopauge Pond to become dangerously low. This led the Town to engage Whitman and Howard to further study groundwater supply sources. Their report recommended the construction of the Quinapoxet Wellfield (built in 1959). The report also recommended the construction of an intermediate reservoir and booster pump to avoid very high system pressures near the Quinapoxet Wellfield. As a result, the Highland Street Concrete Storage Tank was built along with the Highland Street Booster Station to boost water to the normal pressure of the system in Holden Center.

In 1965, the Town of Holden hired Camp Dresser and McKee Inc. (CDM) to examine the adequacy of the supply sources, investigate possible supplemental sources of water and make cost comparisons of alternatives to develop a long-term water supply plan. The study included an extensive groundwater investigation in previously unexplored parts of town as well as consideration of constructing a dam and reservoir on Trout Brook, purchase of additional water from the Metropolitan District Commission (MDC) or purchase of water from the City of Worcester. The report recommended the construction of a wellfield and pumping station at the Mill Street site (constructed in 1967) and a new 12-inch water main and meter vault in Brattle Street in order to purchase water from Worcester (constructed in 1971).

In 1971, CDM performed a comprehensive engineering investigation of the Town's water distribution system. The study included the appraisal of existing distribution mains and storage facilities and concluded with recommendations to improve the present system and enable expansion to meet anticipated demands. The investigation discovered deficient water storage in the Chaffinville area and poor water transmission capacity from Holden Center to supply the Chaffinville section of Town. The report recommended the construction of a new water storage tank in south Holden off Chapin Road. The report also recommended the construction of new water mains to increase transmission capacity from Holden Center to southeast Holden. One water main would travel from Holden Center to the Chaffinville area via the Unionville section of Town. The other water main would connect the proposed tank to southeastern Holden via Newell Road and cross-country to Brattle Street. With these two new water mains installed in the early 1970s, the Town was able to significantly increase the transmission capacity into southeast Holden, which rendered the need to boost water into southwest Holden, via the Adams Street Booster Station, obsolete.

In 1974, CDM was contracted to prepare plans and specifications for the Mason Road Wellfield. This site was identified as a potential site in CDM's "Report on Additional Water Supply for the Town of Holden, Massachusetts" dated July 1966. The wellfield and pump station were constructed in 1975.

Since 1975, CDM has overseen several groundwater exploration programs to identify additional potential municipal public water supplies. In the "Final Report on Phase I Groundwater Exploration Program" dated July 25, 1988, CDM identified the potential for developing a groundwater supply source near Poor Farm Brook. However, the proposed Poor Farm Brook Wellfield (200 gpm) was denied the necessary permits to proceed with construction.

In 1989, CH2M Hill was hired by Holden to verify the storage volume requirements and to establish preliminary design criteria for the previously proposed water storage tank off Chapin Road. CH2M Hill prepared final plans and specifications for the construction of the new water storage tank adjacent to Chapin Road, and the new Chapin Road Booster Station. The tank and pump station were constructed in 1991.

In 1990, the Massachusetts Department of Environmental Protection (MassDEP) notified the Town of Holden that the water supplied by Muschopauge Pond did not comply with the Surface Water Treatment Rule (SWTR) published under 310 CMR 22.20A. On January 12, 1998, CDM presented to the Holden Board of Selectmen five options (Options A through E) that would bring Muschopauge Pond into compliance with the SWTR. Relative to Muschopauge Pond, the Water Management Act (WMA) permit for Holden and Rutland limit the total annual average day withdrawal from pond to the safe yield of 0.55 mgd. Furthermore, according to Chapter 414 of the Acts of 1958, Rutland has primary rights to the Pond; therefore, Holden's withdrawal is limited to the difference between the safe yield and Rutland's annual average day withdrawal. Consequently, as Rutland's demand increases, the volume available for withdrawal by Holden would decrease.

Based on a presentation by CDM, the Board of Selectmen voted to adopt "Option D," to discontinue the use of Muschopauge Pond and reconfigure the distribution system to allow increased water purchase from the City of Worcester as a replacement source. On February 12, 1998, the MassDEP placed the Town of Holden under an Administrative Consent Order (ACO), which delineated a schedule for implementation of "Option D" and dictated that Muschopauge Pond must be placed on "emergency use" status by October 15, 2001.

The implementation of "Option D" required that the distribution system be reconfigured to convey water from the south (Worcester) to the north, while sustaining water pressure and fire flow requirements in northwest Holden. To meet these requirements, CDM submitted a reconfiguration report in October 1998, which listed Phase 1 recommendations to be completed prior to the abandonment of Muschopauge Pond. These recommendations included construction of the 0.75 MG Jefferson Tank in northwest Holden to replace the storage function of Muschopauge Pond and upgrading of the Brattle Street interconnection to ensure that the fully approved amount of water in accordance with the intermunicipal agreement could be provided by Worcester. The upgrade to the Brattle Street interconnection increased the hydraulic grade line above the Chaffin Elevated Storage Tank overflow elevation; such that, the Chaffin Elevated Tank could be removed from service. Other Phase I recommendations that have been completed include installation of pressure reducing valves and installation of a town-wide Supervisory Control and Data Acquisition (SCADA) system. With the full implementation of Option D in October 2001, system pressure in the area of the Chaffin Tank increased considerably, negating the need for this tank such that it was removed from service.

In a letter report dated August 11, 2000, CDM revisited Holden's water supply alternatives and evaluated them according to updated supply and demand projections. The updated projections enabled CDM to identify anticipated water supply deficits and evaluate alternatives that would ensure adequate water supply to meet average and maximum day demands over both short -term (before 2010) and long-term (after 2010) planning periods. Utilizing the short and long-term water supply options, CDM identified five water supply alternatives to meet the Town's projected water demands.

After evaluating the five alternatives, CDM recommended in June 2001 that the Town pursue an interconnection to the City of Worcester's High Service System via Salisbury Street. The interconnection would include a booster station and 7,200-feet of transmission main along Salisbury Street. To ensure adequate water supply for Holden well into the future, CDM recommended that the booster station have an initial capacity of 2.1 million gallons per day (mgd), with expansion capability to 3.0

mgd. In addition to the interconnection, a series of water main improvements were also recommended. The water main upgrades would ensure adequate distribution system pressure and fire flow capabilities to accommodate water supply from the new interconnection on Salisbury Street. The water main improvements include replacing 8,000 feet of 8- and 6-inch water mains, with 12-inch mains on Salisbury Street, Cranbrook Drive and Newell Road.

Design of water main improvements for Salisbury Street (in Holden), Cranbrook Drive and Newell Road were completed in the spring of 2002, and construction was completed in the summer of 2003. Design of the transmission main along Salisbury Street for the booster station was completed in the spring of 2003, and construction was completed in the fall 2004. Design of the underground Salisbury Street Interconnection Booster Station, located near the Holden/Worcester town line, was also completed in the spring of 2003, and construction was completed in the fall 2004. The new Salisbury Street Interconnection Booster Station was placed on-line in September 2004.

1.2 Purpose of Project

The overall goals and objectives of this master planning effort were to evaluate Holden's distribution system, identifying deficiencies and developing a phased improvement list, with cost estimates for a 25-year planning period (2005 – 2030). During the development of the Water System Reconfiguration Report in 1998, a water distribution model of Holden's High Service System and Worcester's Super High Service System was created using Cybernet® 3.1 by Haestad Methods of Waterbury, Connecticut. For this Master Plan, the water distribution system model has been expanded to include Holden's Low Service System and has been upgraded to the newest version of the software called WaterGEMS® 3.0. Efforts have also focused on recalibrating, as appropriate, the High Service System portion of the model and validating the model based on operations data from Holden's SCADA system. In addition, CDM has evaluated system reliability and developed future water system demands. Evaluation of SDWA impacts on the town's supply sources has been conducted and submitted under separate cover.

1.3 Project Scope

The following major tasks have comprised the scope of this project:

- ***Data Collection***. Collect and review all available information on the Holden water system, including Department of Public Works record plans, subdivision plans, pumping station data, past engineering reports, and other facilities information needed to model the pipe network.

- ***Water Quality Assessment***. Review Holden's current water quality and evaluate how the current and impending SDWA rules, regulations and guidelines may impact the Town. This assessment has been submitted under separate cover.

- ***Computer Model Development***. Expand the existing computer model of Holden's High Service System and Worcester's Super High Service System to include Holden's Low Service System. Calibrate and validate the model to within an acceptable level of accuracy.

- ***Field Testing***. Develop and perform a field testing program, including hydrant flow tests and C-value tests. Use data obtained in the field testing program to calibrate the hydraulic model.

- ***Distribution System Piping Analysis***. Utilize simulations of the calibrated hydraulic model to identify piping deficiencies in the distribution system under projected peak hour and maximum day with fire flow demands and operating conditions for 2030.

- ***Distribution System Storage Analysis***. Review storage capacity within the distribution system during normal operation and emergency situations to determine its ability to provide adequate storage during future demand conditions.

- ***Distribution System Reliability Analysis***. Review pumping capacities at all water supply sources and booster stations during normal operation and emergency situations to determine their ability to meet estimated future water supply requirements.

- ***Development of Recommended Improvements***. Evaluate alternatives and recommend improvements to upgrade the existing system. Prioritize the recommended improvements on the basis of need and overall impact on the system.

- ***Recommend an Annual Maintenance Program***. Develop recommendations for annual distribution system maintenance to ensure proper operations and assist in permit compliance.

- ***Cost Estimating***. Prepare construction cost estimates for each recommended distribution system improvement.

- ***Report Preparation***. This engineering report summarizes the results of the distribution system evaluation.

1.4 Report Organization

This report is divided into the following sections:

- ***Section 2, Description of Existing System***. Overview of Holden's water distribution system and its major components.

- ***Section 3, Population and Demand Projections***. Description of methods used to develop population projections and future demands.

- ***Section 4, Fire Flow Requirements***. Discussion of ISO study and current fire flow requirements.

- ***Section 5, Distribution System Model Development***. Overview of the water distribution system model development, including a discussion of water demand allocation, field testing results and calibration methods.

- ***Section 6, Distribution System Evaluation***. Description of the criteria used in the distribution system evaluation, overview of the distribution system evaluation and discussion of the results of the distribution system evaluation.

- ***Section 7, Recommended Improvements to the Distribution System***. Recommendations and cost estimates for distribution system improvement programs. Included in this section is a discussion of annual preventative maintenance programs.

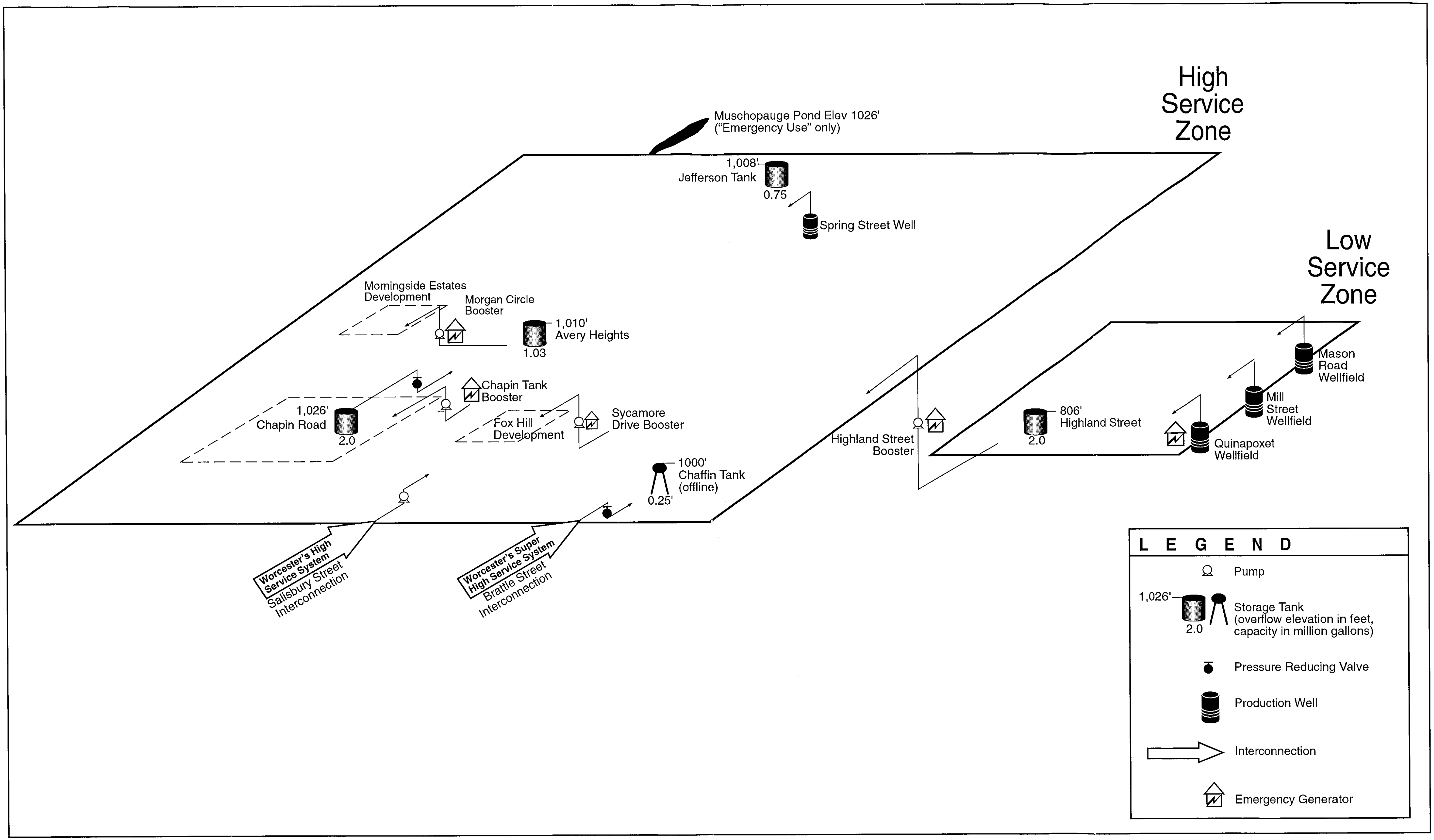
Section 2
Description of Existing System

2.1 General

This section summarizes the Town of Holden's water distribution system. Presently, the distribution system is divided into two major pressure zones to serve the range of elevations of the water service areas. The elevation boundary between these two systems is approximately parallel to Main Street, following the 750 800 foot (228 243 meter) topographic contour. An isometric plan showing these service zones and all existing facilities within the water system is included as Figure 2-1.

Holden's high service system includes: Jefferson Tank (storage), Avery Heights Standpipe (storage), Chaffin Elevated Tank (storage, off-line), Chapin Road Tank (storage) and associated Chapin Booster Station (pumping facilities), the Spring Street Well (supply), the Brattle Street interconnection with Worcester (supply), the Salisbury Street interconnection with Worcester (supply), Muschopauge Pond (emergency supply), and the transmission and distribution mains serving these facilities. The high service system also contains two active booster stations, Sycamore Drive Booster Station and Morgan Circle Booster Station, to supply water to residential developments. The Holden high service system was originally designed to convey water from northwest Holden (Muschopauge Pond) to southeast Holden (Chaffin Area). However, following the removal of Muschopauge Pond from service in October 2001, water in Holden's high service system now primarily flows north from the Brattle Street and Salisbury Street Interconnections with the City of Worcester.

The Low Service System includes the Mason Road Wellfield (supply), the Mill Street Wellfield (supply), the Quinapoxet Wellfield (supply), the Highland Street Reservoir (storage), the Highland Street Booster Station and the distribution mains serving these facilities. The Low Service System was designed to feed the High Service System through the Highland Street Booster Station. The Highland Street Booster Station pumps water either stored in the Highland Street Reservoir or supplied by the Quinapoxet Wellfield, the Mill Street Wellfield and/or the Mason Road Wellfield.



CDM
4/4/06

Figure 2-1
Water System Isometric Plan
Town of Holden, Massachusetts

2.2 Supply Sources

All of the Town's water is supplied by the following sources. Table 2-1 provides a summary of the groundwater well facility information.

Spring Street Well - The Spring Street Well is located off Spring Street near the Department of Public Works Garage. The original well was constructed in 1954 with an original capacity of 250 gpm; however, flow data in recent years indicated that the original well was producing less than 100 gpm. Due to high levels of iron and manganese and the inability to sustain the well's capacity through redevelopment, CDM recommended in 2002 that the Town of Holden construct a replacement well to improve water quality and maintain the current MassDEP approved pumping rate of 140-gpm. Design and installation of the replacement well was completed in the summer of 2003, with the connection facilities from the replacement well to the existing well station constructed in the fall of 2004. To enable the connection to existing discharge piping in the well station, the pump and motor from the original Spring Street Well were removed and the well was abandoned. The new Spring Street Replacement Well went on-line in February 2005.

In 2001, construction of the Spring Street Chemical Feed Facility was completed. This facility provides corrosion control (potassium hydroxide), fluoridation (sodium fluoride), and disinfection (sodium hypochlorite) chemicals to the existing well station. After receiving treatment from the Chemical Feed Facility, water from the well pumps directly into the distribution system. Well operation is not tied directly to any of the storage facilities.

Quinapoxet Wellfield - The Quinapoxet Wellfield, located off of Wachusett Street, is comprised of two gravel-packed wells. A Zone II delineation of this wellfield is in process with an expected MassDEP approved pumping rate of 514 gpm. The Quinapoxet Wellfield operates based on the water level of the Highland Street Reservoir and typically runs 24 hours a day. In 2001, a diesel driven standby generator within a sound attenuated enclosure was installed at the Quinapoxet Wellfield. In addition, the electrical facility that supplied the wells was replaced with an updated electrical system located within the standby generator enclosure.

In 2005, a new permanent corrosion control treatment facility was constructed at the Quinapoxet Wellfield to treat water from both the Quinapoxet Wellfield and the Mill Street Wellfield. The new facility provides corrosion control (potassium hydroxide) and fluoridation (sodium fluoride), with room to install sodium hypochlorite for disinfection in the future, if needed.

Mill Street Wellfield - The Mill Street Tubular Wellfield is located off of Mill Street. A Zone II delineation of this wellfield is in process with an expected MassDEP approved pumping rate of 208 gpm. Similar to the Quinapoxet Wellfield, the Mill Street Wellfield operates based on the water level of the Highland Street Reservoir and runs 24 hours a day. As stated above, a new permanent corrosion control treatment facility was constructed in 2005 at the Quinapoxet Wellfield to treat water from both the Quinapoxet Wellfield and the Mill Street Wellfield.

Mason Road Wellfield - The Mason Road Tubular Wellfield is located off Mason Road. A Zone II delineation if this wellfield is in process with an expected MassDEP approved pumping rate of 111 gpm. This wellfield also operates based on the Highland Street Reservoir. In addition, the wellfield shuts down under low pressure (vacuum) condition and remains off-line for 6 hours to allow the water level to recover.

Current treatment at the Mason Road Wellfield includes temporary corrosion control (potassium hydroxide) and fluoridation (sodium fluoride). In accordance with the ACO, CDM has completed design of a permanent corrosion control facility to serve the wellfield; however, construction of the facility is on-hold pending an evaluation of wellfield operation and an economic comparison of the cost of supplying water from the Mason Road Wellfield versus the cost of purchasing water from Worcester. If Holden elects to place the Mason Road Wellfield on emergency status, the installation and implementation of permanent corrosion control facilities will not be required. The Town is also discussing with MassDEP the possibility of placing the Mason Road Wellfield on stand-by status. In this case, all water quality testing would be kept up to date for the well, but the wellfield would only be used on an intermittent or stand-by basis. If this is acceptable to MassDEP, the Town would then continue to use the existing temporary corrosion control facilities.

Table 2-1
Groundwater Supply Facilities

Groundwater Supply Facility	No. of Wells	Size of Well	Type of Well	Year Installed	DEP Approved [1] Pumping Rate (gpm)	DEP Approved [1] Max Daily Volume (MGD)	Well Depth (ft)
High Service System							
Spring Street Well	1	48"x24"	Gravel Packed	1958	Offline	Offline	40
Spring Street Replacement Well	1	16"x10"	Gravel Packed	2003	140	0.20	42
Low Service System							
Quinapoxet Wellfield	2	48"x24"	Gravel Packed	1959	514	0.74	Well 1 – 41 Well 2 – 37
Mill Street Wellfield	27	2½"	Tubular	1966	208	0.30	22-40
Mason Road Wellfield	15	2½"	Tubular	1977	111	0.16	21-26

Note: 1. Only Spring Street Well has a DEP Approved rate/volume per the Town's Water Management Act (WMA) permit. DEP Approved rates/volumes for the remaining wells are expected to be added upon Zone II completion and approval.

Muschopauge Pond – In accordance with the ACO, Holden placed Muschopauge Pond on emergency status on October 15, 2001. However, the Town maintains the basic rights to the pond. Emergency/short-term water supply use of Muschopauge Pond would require public notice and a boil water order to be put in place. Future/long-term use of the Pond would require water treatment in a manner fully compliant with the SDWA regulations in effect at that time. In addition to complying with SDWA regulations, use of Muschopauge Pond would have to comply with the Town's Water Management Act (WMA) permit. Currently, the WMA permit for Holden and Rutland limit the total annual average day withdrawal from Muschopauge Pond to the safe yield of 0.55 mgd. According to Chapter 414 of the Acts of 1958, Rutland has primary rights to the Pond; therefore, Holden's withdrawal is limited to the difference between the safe yield and Rutland's annual average day withdrawal. As Rutland's demand increases, the volume available for withdrawal by Holden would decrease.

The pond is located in Rutland, Massachusetts and formerly operated as a source of water supply and storage for Holden's high service system. It has a legal high water elevation of 1029.5 feet above mean sea level (MSL). The pond has a water surface area of about 60 acres, a usable storage capacity of 340 million gallons (MG) above 1008 feet MSL and a normal operating range between 1020 feet MSL and 1029 feet MSL. In the top 10 feet of depth, there is an average 18 MG of storage per foot of depth.

2.3 Distribution System Interconnections

The Town has two active interconnections with the City of Worcester, Brattle Street and Salisbury Street. A third existing interconnection with the City of Worcester is located at the intersection of Holden Street and South View Road within Worcester. According to Worcester, this interconnection has never been used.

Brattle Street Interconnection with Worcester - Worcester's Super High System supplies water for Holden's High Service System through the Brattle Street Interconnection. In 2000, as part of "Option D," the Town of Holden upgraded the Brattle Street interconnection to ensure up to 1.5 MGD of water could be supplied by the City of Worcester through the interconnection. According to the new intermunicipal agreement with the City of Worcester (dated November 18, 2002), which expires 99 years from the date that Holden first draws water through the Salisbury Street Booster Station interconnection (October 1, 2004), the maximum purchase through the Brattle Street interconnection was reduced from 1.5 MGD to 1.0 MGD. This reduction is also stated in correspondence governing the Interbasin Transfer Act (ITA) approval for the new Salisbury Street Interconnection.

The Brattle Street interconnection was originally designed to operate when system pressures in the Chaffin Elevated Tank area fell below 80 psi and until the system pressures reached 86 psi. However, when the Chapin Road Tank and the Chapin Booster Station were constructed in 1991, the operation of the Brattle Street interconnection was modified. Based on these modifications, the Brattle Street interconnection would open via telementry to supply water from the Worcester to help prevent dangerously low pressures from developing when the Chapin Booster Station was operating to refill the Chapin Road Tank.

With completion of the Brattle Street upgrade and the installation of Town-wide SCADA, the Brattle Street interconnection currently operates as follows:

- When the Avery Heights Tank falls below a preset elevation;
- When the Chapin Booster Station is operating to refill the Chapin Road Tank; and,
- When the distribution system pressure falls below a preset level.

Once the SCADA system signals the Brattle Street Interconnection to operate, the Brattle Street valve opens to maintain either a preset flow rate or the preset pressure, whichever is lower.

Salisbury Street Booster Station Interconnection – The Salisbury Street Booster Station Interconnection went on-line in September 2004. The new 2.1 MGD below ground booster station interconnection pumps water from Worcester's High Service System into the Town of Holden's High Service System. Approximately 6,000-ft of new 24-inch suction side transmission main was installed to connect the interconnection booster station to Worcester's 42-inch High Service System water main at the intersection of Moreland and Salisbury Streets. In addition, approximately 1,200-ft of new 16-inch discharge side transmission main was installed to connect the new booster station to Town of Holden's High Service System near the intersection of Salisbury Street and Stanjoy Road.

The new intermunicipal agreement between Holden and Worcester executed on November 18, 2002, allows an annual daily average withdrawal of 2.0 MGD and a maximum daily withdrawal of 3.0 MGD from the new Salisbury Street interconnection. In accordance with the Town's current ITA permit, the daily flow through the new Salisbury Street interconnection is restricted to 2.1 MGD. Additional ITA permitting will be required to increase flow above 2.1 MGD from the Salisbury Street interconnection.

2.4 Distribution System Storage

The following describes the Town's water storage facilities and Table 2-2 provides a summary of water storage tank facility information:

Avery Heights Standpipe - The Avery Heights standpipe is a welded steel water storage tank located near Holden Center. The tank has a capacity of 1.0 MG and overflow elevation at 1,010 feet MSL. The Avery Heights Tank has an operating range of approximately two thirds full (elevation 993 feet MSL) to full (elevation 1,010 feet MSL), except in the summer when it operates approximately half full (elevation 984 feet MSL) to full (elevation 1,010 feet MSL). The water level in the Tank controls the operation of the Highland Street Booster Station.

Chaffin Elevated Tank - The Chaffin Elevated Tank is a welded steel elevated water storage tank located just off Shrewsbury Street and just east of Brattle Street. The tank has a capacity of 0.25 MG, and an overflow elevation of 1,000 feet MSL. The tank was taken offline as part of the "Option D" - Phase I recommendations.

Chapin Road Reservoir - The Chapin Road Tank is a welded steel water storage tank located off Sycamore Drive. The tank has a capacity of 2.0 MG and an overflow elevation of 1026 feet MSL. The water level in the Chapin Road Tank controls the operation of the Chapin Booster Station. The normal operating water level within the Chapin Road tank is between 1020 and 1024 feet MSL.

Jefferson Reservoir - As part of "Option D," the Town of Holden constructed the Jefferson Water Storage Tank to replace the storage function of the Pond to ensure adequate fire protection. The tank is a 750,000 gallon welded steel storage tank located in northwest Holden, with an overflow elevation of 1008 feet MSL.

Highland Street Reservoir - The Highland Street Reservoir is a reinforced concrete tank located on Highland Street (Route 31). The tank has an original capacity of 2.0 MG and an overflow elevation of 806 feet MSL. In May 1983, the tank suffered a catastrophic failure and released approximately 2.0 MG of water. The tank was subsequently rebuilt and put back on-line in November 1986. However, because of the 1983 failure, the Town currently limits water level within the tank to an overflow elevation of 801 feet MSL, which results in a total capacity of approximately 1.5 MG. The reservoir does not have an altitude valve; however, the operation of the low service wells is controlled via telemetry by the water level within the tank. The Highland Street Reservoir receives water from all the low service system wellfields (Mason Road, Mill Street and Quinapoxet).

Table 2-2
Water Storage Facilities

Storage Facility	***Type of Tank***	***Year Built***	***Capacity (MG)*** [1]	***Height (ft)***	***Tank Diameter (ft)***	***Overflow Elevation (ft-MSL)*** [1]
High Service System						
Avery Heights Standpipe	Welded Steel	Mid 1950s	1.0	52	58	1,010
Chaffin Elevated Tank [2]	Welded Steel	Mid 1950s	0.25	32	40 (3)	1,000
Chapin Road Reservoir	Welded Steel	1991	2.0	32	104	1,026
Jefferson Reservoir	Welded Steel	2001	0.75	15	92	1,008
Low Service System						
Highland Street Reservoir	Reinforced Concrete	Late 1950	2.0 (4) 1.5 (5)	23 (4) 18 (5)	120	806

Note:
1. MG = Million Gallons; ft-MSL = feet with respect to Mean Sea Level
2. Chaffin Tank currently off-line
3. Diameter at midpoint
4. Original Highland Street Reservoir Capacity and Water Level
5. Current Highland Street Reservoir Capacity and Water Level

2.5 Distribution System Booster Stations

The following describes the Town's water distribution system booster stations:

Highland Street Booster Station - The Highland Street Booster Station is located within a below grade vault in the shoulder of Highland Street (Route 31) and contains two submersible "can" style vertical turbine pump, each with a capacity of approximately 700 gpm. This allows for one active pump with one standby pump. In 2001, a diesel driven standby generator within a sound attenuated enclosure was installed at the Highland Street Reservoir to provide emergency power to the Highland Street Booster Station.

Water is transferred from the Highland Street reservoir to the high service system by one submersible "can" style vertical turbine pumps housed in the Highland Street Booster Station vault. When the water level in the Avery Heights (Standpipe) Tank drops to a certain elevation, the SCADA system signals the Highland Street Pumping Station to come on, thereby boosting water from the low service system to the high service system. When the level in the Avery Heights (standpipe) reaches a preset elevation, the SCADA system signals the Highland Street Booster Station to turn off. Similarly, when the water level within the Highland Street Reservoir drops to a preset elevation, the SCADA system signals the Highland Street Booster Station to turn off.

Chapin Tank Booster Station - The Chapin Tank Booster Station is located on Sycamore Drive and contains two 25 hp end suction style pumps, each with a capacity of approximately 400 gpm and an emergency standby generator. When the water level in the Chapin Road tank drops to a preset elevation, the SCADA system signals one pump at the Chapin Booster Station to operate and the Brattle Street Interconnection with the City of Worcester to open. Similarly, when the Chapin Road tank reaches another preset elevation, the SCADA system signals the Chapin Booster Station to shut off and the Brattle Street connection to close. In addition, the operation of the Chapin Booster Station is limited to the hours of 10:00 pm and 6:00 am by Holden Water Department Personnel through the SCADA system.

Sycamore Drive Booster Station - The Sycamore Drive Booster Station exists to serve approximately 50 homes in the Fox Hill Development area. The original station included one jockey pump and three lead/lag pumps. Currently, there are only two 7.5 hp pumps in service, which allows for one active pump with one standby pump. Each pump has a capacity of 150 gpm and is connected to a Hydroconstant® variable speed drive. A Hydroconstant® drive is a fluid coupling designed to allow variable pump shaft speed in response to water pressure. The Sycamore Drive Booster Station also contains an emergency standby generator. In the event of a fire in the Fox Hill Development area, there is a check valve located at the Sycamore Drive Booster Station, which will allow water to enter the area directly from the high service system.

Morgan Circle Booster Station - The construction of the Morningside Estates, between Greystone Drive and Avery Heights Drive, required the installation of the

Morgan Circle Booster Station. The booster station was designed to serve approximately 150 homes in this area, and replace the aging Avery Heights and Reservoir Street Booster Stations.

The Morgan Circle Booster Station contains one 3-hp jockey pump, one 20-hp lead pump, and two 40-hp lag pumps. The pumps are end suction type pumps and station includes an emergency standby generator. The lead pump has a capacity of approximately 500 gpm and the lag pumps have a capacity of approximately 1,200 gpm each. The total capacity of the station is approximately 2,100 gpm. The lead pump is equipped with an electronic variable frequency drive, which controls the lead pump speed to maintain the desired pressure within the service area. The operation of the pumping system is controlled by a local control panel, which controls the number of pumps in operation and the pump operating sequence in order to maintain the desired flow and pressure within the service zone.

Avery Heights Booster Station - The Avery Heights Booster Station was designed to boost water pressure for homes located in close proximity to the Avery Heights Tank. The Avery Heights Booster Station is offline and has been replaced by the Morgan Circle Booster Station.

Reservoir Street Booster Station - The Reservoir Street Booster Station was installed to boost water to homes located on Reservoir Street. The Reservoir Street Booster Station is offline and has been replaced by the Morgan Circle Booster Station.

Adams Road Pumping Station - The Adams Road Pumping Station was installed to remedy low pressure created by high demands in the Chaffin section; however, this booster station is no longer utilized since the Chaffin area is now adequately looped.

2.6 Distribution System Piping

Holden's distribution system includes approximately 105 miles of water mains, with 90 percent of the water mains located within the high service system. Originally, the Town of Holden's water distribution system was installed using unlined cast iron water mains. In 1904, the Town's first installed water mains were the large diameter unlined cast iron pipes from Muschopauge Pond into Holden Center. These large diameter water mains have since been cleaned and lined from Muschopauge Pond to the intersection of Main Street and Highland Street. It is estimated that there are approximately 25 miles of cast iron water mains in the Town's water system with approximately 4 miles having been cleaned and cement lined. The Town then transitioned to asbestos cement water main. From approximately 1950 to the mid-1970s, the Town installed 45 miles of asbestos cement water main. The Town's current water main standard is to install cement lined ductile iron pipe. It is estimated that there are approximately 35 miles of cement lined ductile iron water mains in the Town's water system. (See Appended Water Distribution System Map).

Section 3
Population and Demand Projections

3.1 General

To determine the water system improvements required to adequately satisfy Holden's future needs, population trends were reviewed and water consumption projections were developed.

3.2 Past Population Trends and Future Population Projections

Historic and future population trends are generally used to predict future water consumption for a community. In order to estimate the future water supply needs for the town, past population trends and future population projections from several independent sources were reviewed. The various sources were:

- United States Census Bureau (USCB)
- Town Clerk's Office, Town of Holden
- Massachusetts Institute for Social and Economic Research (MISER)
- Central Massachusetts Regional Planning Commission (CMRPC)

Table 3-1 and Figure 3-1 show the historic census population in Holden from 1920. In general, the population of the town has steadily grown since 1920, as residents continue to seek suburban homes. While the rate of growth from 1920 to 1930 was 30 percent, population remained nearly constant from 1930 to 1940. From 1940 to 1950 and 1950 to 1960, Holden experienced its greatest growth rate of 52 percent and 69 percent, respectively. However, this significant population growth did not last, since the rates of growth from 1960 to 2000 for each ten-year period were 24, 6, 10, and 7 percent, respectively.

Table 3-1
USCB Population Census

Year	*USCB Population Count*	*Percentage Increase/Decrease Over Previous Census Year*
1920	2,970	--
1930	3,871	+30
1940	3,924	+1.4
1950	5,975	+52
1960	10,117	+69
1970	12,564	+24
1980	13,336	+6.1
1990	14,628	+10
2000	15,621	+6.8

USCB: United States Census Bureau

In addition to the USCB data, the Town Clerk's Office also develops annual population estimates for the Town of Holden. The Town Clerk's Office annual population estimates for Holden from 1990 to the present are listed in Table 3-2 and shown in Figure 3-1:

Table 3-2
Town Clerk Population Census

Year	Town Clerk Population Count	Percentage Increase/Decrease Over Previous Year
1990	14,767	--
1991	14,895	+0.9
1992	15,017	+0.8
1993	15,191	+1.2
1994	15,178	-0.1
1995	15,240	+0.4
1996	15,384	+0.9
1997	15,505	+0.8
1998	15,750	+1.6
1999	15,730	-0.1
2000	15,911	+1.2
2001	16,184	+1.7
2002	16,455	+1.7
2003	16,695	+1.5
2004	17,072	+2.3

Source: Town Assessor

In 2003, MISER released the latest population projections for Massachusetts and its counties, cities and towns for the years 2010 and 2020. The latest population projections incorporate the 2000 U.S. Census information and include a middle, high, and low projection series. The MISER population projections for Holden are listed below:

Year	Low Population Projection	Mid Population Projection	High Population Projection
2010	14,964	15,504	16,058
2020	14,180	15,453	16,818

Source: MISER, 2003

The MISER's high population projection for Holden is shown on Figure 3-1.

CMRPC, a planning partnership serving central and southern Worcester County communities in the areas of growth and development management, transportation planning, information coordination and data management, regularly updates population forecasts to reflect recent trends. According to the latest CMRPC 2003 Regional Transportation Plan Interim Update forecast, Holden's projected population is listed below and shown in Figure 3-1:

Year	***Projected Population***
2010	16,928
2015	17,596
2020	18,292
2025	18,976
2030	19,802

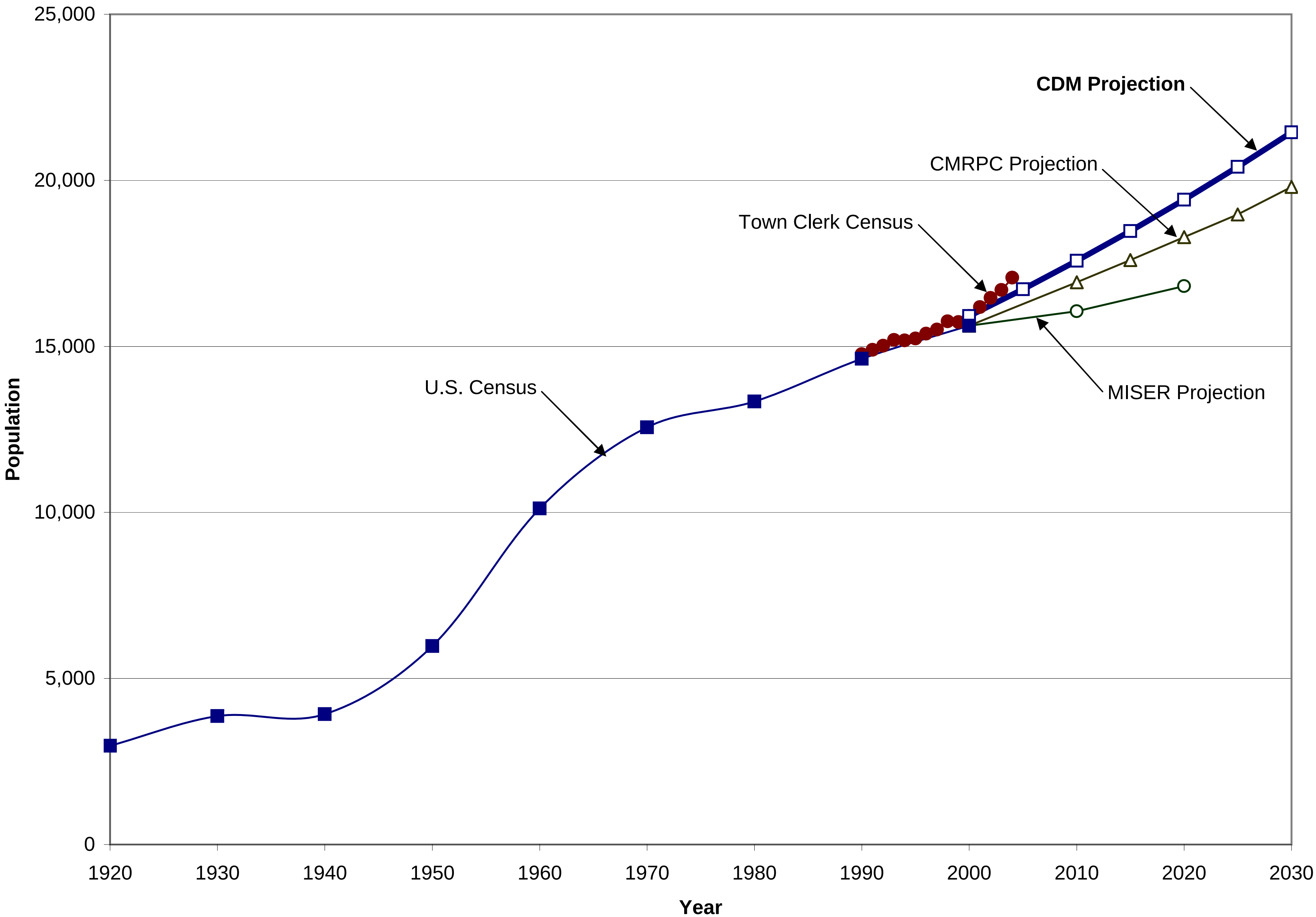
Source: CMRPC, 2003

As part of the Water Supply Alternatives Evaluation Report, dated August 11, 2000, CDM projected Holden's future population based on the Town Clerk's population estimate data from 1990-2000. As a result, an annual increase of 1 percent was used to project Holden's future population as listed below and shown in Figure 3-1:

Year	***Projected Population***
2005	16,723
2010	17,576
2015	18,472
2020	19,414
2025	20,405
2030	21,446

Source: CDM, 2000

As stated above, the population in Holden has increased significantly since 1920. While the population increase in Holden has slowed over the past three decades, it is expected to continue to increase at a rate of approximately 1 percent per year for the foreseeable future, which is slightly higher than projected by the MISER and CMRPC. It is important to note that standard forecasting techniques usually do not account for less tangible factors that would help sustain the current growth pattern. These less tangible factors include: road upgrades, new sewer system installation, water system improvements, new school construction, and the Main Street corridor improvements. Due to all the recent improvement projects in Holden, the Town will continue to be an attractive community ripe for growth. Therefore, for this study, CDM has adopted the population projections developed for the August 2000 Water Supply Alternative Evaluation Report. This projection rate increase in population represents a conservative approach for water distribution system planning.



CDM

Figure 3-1
Population Trends and Projections
Town of Holden, Massachusetts

3.3 Water Consumption Trends and Projections

To develop water consumption projections, CDM reviewed historical water consumption records. The Massachusetts DEP Annual Water Supply Statistical Reports were compiled for the period 1990 through 2004. Future consumption projections were then developed based on trends in historical water consumption.

3.3.1 Water Consumption Definitions

The rate of water consumption varies hourly and daily. Average day consumption (or demand) is defined as the average daily consumption of water based on the yearly total consumed. Based on average daily consumption and population, the average daily system-wide per capita water consumption can be determined. The average daily system-wide per capita water consumption includes residential, commercial, industrial, municipal and unaccounted-for water. The average daily system-wide per capita water consumption figure is then combined with population projections to develop future average day water consumption.

Maximum day consumption (or demand) is defined as the largest amount of water used in one day during a particular year, which generally occurs during the summer months when water consumption is highest. The ratio of maximum day to (annual) average day demand is usually calculated to aid in making future maximum day demand projections. This ratio is primarily a function of:

- Magnitude of the average day demand (i.e., the larger this demand, the smaller the ratio);
- Variability of the climate (i.e., the smaller the range in temperature, the smaller the ratio; the more evenly distributed the rainfall, the smaller the ratio);
- Magnitude of system pressure (i.e., the lower the pressure, the smaller the ratio); and,
- Amount of system leakage (i.e., the larger the percentage of system leakage, the smaller the ratio).

In addition, this ratio is also a function of the relative importance of each component of the total demand (i.e., residential, commercial and industrial). The ratio of maximum to average day demand is generally higher for residential than for commercial and industrial consumers, caused by such domestic activities as lawn sprinkling, car washing, and swimming pool filling. The water supply system should be capable of delivering a flow equal to the highest projected maximum day demand.

Peak hour demand is defined as the largest amount of water used in one hour within a particular year. Like the maximum day demand to average day demand ratio, peak hour demand ratio is usually calculated by dividing the peak hour demand by the (annual) average day demand. The peak hour ratio is also a function of the above-cited factors, and is another factor used in sizing of distribution system facilities.

3.3.2 Historic Water Consumption

According to the Mass DEP Public Water Supply Annual Statistical Reports, the average and maximum day demand has generally increased from 1990, which parallels the population increase over the same period. The average and maximum day demands from 1990 to 2004 are listed in Table 3-3.

The historical system-wide per capita water demand for 1990 to 2004 is also shown in Table 3-3. According to Holden's Department of Public Works, only 90 percent of Holden residents are served by public water on a town-wide basis. In addition, the Holden distribution system provides water to approximately 200 residents in Worcester.

According to the data, the system-wide average daily per capita water consumption ranged from a high of 113 gpcd in 1998 to a low of 78 gpcd in 2003. The maximum-to-average day ratio ranged from a high of 2.04 in 1994 to a low of 1.64 in 1992. The system-wide per capita demand and the maximum-to-average day ratio during the past 15 years are typical values for similarly sized communities, especially considering that the average system-wide per capita demand and maximum-to-average day ratio includes unaccounted-for-water, commercial, industrial and municipal water consumption.

From 1994 to 1998, Holden's unaccounted-for-water was greater than 25 percent. In November 1998, a significant leak was found and repaired; in addition, the flow recording meter at the Spring Street Well Station was replaced. Therefore, the system-wide per capita demand during that period was slightly higher than would be expected, and the maximum-to-average day ratio was slightly lower than would be expected. Similarly, from 2001 through 2004, the Town of Holden was under mandatory watering restrictions. As a result, the system-wide per capita demand and the maximum-to-average day ratio were slightly lower than would be expected.

Based on the data in Table 3-3, a system-wide per capita demand value of 100 gpcd and a maximum-to-average day ratio of 2.0 appears reasonable for use in projecting future average day and maximum demands. The system-wide per capita demand of 100 gpcd and the maximum-to-average day ratio of 2.0 is based on 1999 water use data, as compared to earlier years when unaccounted-for-water was significant and later years when the Town was subject to a watering ban. In addition, according to the MassDEP 2001 Guidelines and Policies for Public Water System, a system-wide per capita demand of 100 gpcd is recommended when determining the average volume of water necessary to support a particular number of residents within a water distribution system.

3.3.3 Water Consumption Projections

As part of the Water Supply Alternatives Evaluation Report, dated August 11, 2000, CDM projected Holden's future population based on the Town Clerk's population estimate data from 1990-2000. As a result, an annual increase of 1 percent was used to project Holden's future population as listed in Table 3-4. To develop the projected system-wide population, it was assumed that only 90 percent of Holden residents and 200 Worcester residents would be served by Holden's public water supply system.

As discussed above, to develop the projected system-wide average day demand, the projected system-wide population was multiplied by the system-wide per capita demand of 100 gpcd. Similarly, to develop the projected system-wide maximum day and peak hour demand, the system-wide average day demand was multiplied by the maximum-to-average day ratio of 2.0 and a peak hour-to-average day ratio of 3.5. The peak hour-to-average day ratio was estimated from the "Relation of Extreme Discharge on Maximum and Minimum Days to the Average Daily Discharge of Domestic Sewage" for Merrimack Valley communities, which is also known as the Merrimack Curve.

3.3.4 Residential per Capita Consumption

Holden completed a town-wide water meter replacement program in 2005. With the availability of the new consumer metering technology implemented by the Town, it is now possible to develop a more detailed account of water use, by such categories as: residential, commercial, industrial, municipal, agricultural, unaccounted-for water, etc. This detailed accounting of water use is typically referred to as a water audit. By dividing the total residential consumption (in gallons per day) by the number of residents (capita), a residential per capita demand can be estimated and is typically referred to in residential gallons per capita per day (rgpcd) units. Once two years of meter data is available, the Town will be able to develop a more accurate account of water use and residential per capita demand estimate. On a preliminary basis, the Town currently estimates a residential per capita demand of 69 rgpcd.

Section 4
Fire Flow Requirements

4.1 General

The ability of the distribution system to meet fire flow demands was evaluated using fire flow requirements established for the Town of Holden by the Insurance Services Offices (ISO).

4.2 ISO Background

The ISO is an independent organization that services insurance companies and fire departments. ISO compiles and analyzes data about municipal fire protection and assigns a Public Protection Classification (PPC), which is used by insurance companies to establish insurance premiums for fire protection policies for both residential and commercial buildings. Forty percent of a community's PPC depends on the water supply system and the amount of available water compared with the amount needed to suppress fires. ISO estimates needed fire flow requirements at representative locations throughout the community, as described in Section 4.3. Accordingly, only fire flow requirements for a small portion of the community are actually estimated by ISO.

To determine if the amount of available water exceeds the amount needed to suppress fires, ISO analyzes the capacity of the supply facilities, the capacity of the water distribution system and the distribution of hydrants. ISO first determines the capacity of the supply system through an analysis of the water sources, treatment facilities, transmission facilities, storage facilities and the ability of these facilities to provide the needed fire flow. Then, ISO determines the capacity of the water distribution system by observing actual hydrant flow tests at each representative location. Finally, ISO evaluates hydrant distribution by examining the number and type of hydrants within 1,000 feet of each representative building.

4.3 ISO Required Fire Flow Methodology

To determine the required fire flow rate, ISO uses the Fire Suppression Rating Schedule. Fire flow requirements represent the available flow at a 20 psi residual pressure. Generally, each location is rated based on the building in the area with the largest rated fire flow requirement.

Estimates for fire flow requirements for commercial buildings are based on a complex formula considering land use, building construction, occupancy characteristics, spacing between buildings, and the existence of individual building fire protection systems. Estimates of fire flow for specific commercial/industrial buildings are typically completed by a representative of ISO.

Generally, the water system must deliver a fire flow up to 3,500 gpm at a 20 psi residual pressure to obtain the best overall citywide insurance rating. Large commercial, institutional, and industrial premises with fire protection needs that exceed 3,500 gpm must be supplied by individual fire protection connections and fire pumps, if necessary, to meet the requirements. The provision of this additional flow, above the 3,500 gpm requirement, is generally the responsibility of the owner of the building. In these cases, ISO often reports both the estimated required fire flow and the officially recognized lower required fire flow limit. Alternately, a sprinkler system can be used to reduce the fire flow requirements for these larger buildings.

In contrast, fire flow requirements for residential areas are relatively simple to estimate using ISO guidelines. For 1 or 2 family dwellings not exceeding two stories in height, the fire flows are listed in Table 4-1.

Table 4-1
ISO Fire Flow Requirements for 1- or 2- Family Dwellings

Distance Between Buildings	*Needed Fire Flow*
over 100 feet	500 gpm
31 to 100 feet	750 gpm
11 to 31 feet	1,000 gpm
10 feet or less	1,500 gpm

4.4 ISO Results

Table 4-2 and Table 4-3 lists the results of ISO's 1991 and 2003 fire flow testing programs in Holden; included are the locations of the test, as well as available and required fire flow quantities. The ISO required fire flow at a residual pressure of 20 psi is calculated based on building construction type, building occupancy classification, space between buildings, and individual fire protection systems. Holden's water distribution system will be first analyzed against the ISO required fire flows shown in Table 4-2 and Table 4-3.

Table 4-2
1991 ISO Fire Flow Test Data Summary

Test No.	Location	Gauge Hydrant Pressure (psi)		Flow Rate (gpm)		
		Static	Residual	Flow Tested	Flow at 20 psi	
					Required	Available
1	Moscow Rd/Wachusett St	61	45	1,040	500	1,700
2	Wachusett St/River St	80	77	2,440	1,000	adeq.
3	Torrey Lane/Hawthorne Rd	105	56	670	750	900
4	Salisbury St/Fisher Rd	68	36	890	750	1,100
5	Shrewsbury St/Holden St	100	90	1,230	3,500	3,800
6	Pinecroft Ave/Cook St	74	54	1,160	750	2,000
7	Industrial Dr/Main St	118	100	1,560	3,000	3,900
8	350 Bullard St	80	66	1,320	3,000	2,900
9	Wachusett St/Bullard St	160	159	1,420	500	adeq.
10	Boyden Rd/Main St	76	70	1,220	3,000	4,100
11	268 Reservoir St	55	52	1,060	3,000	4,000
12	Greenwood Pkwy/Lovell Rd	78	39	1,010	750	1,300
13	1401 Main St/High St	84	78	1,380	5,000/2,000	5,000
14	Quinapoxet St/Windy Ridge Rd	116	68	1,120	750	1,600
15	1747 Main St/Princeton St	85	71	1,310	4,000/2,250	3,000
16	N Main St/Cutler Rd	36	22	920	1,250	1,000

Table 4-3
2003 ISO Fire Flow Test Data Summary

Test No.	Location	Gauge Hydrant Pressure (psi)		Flow Rate (gpm)		
		Static	Residual	Flow Tested	Flow at 20 psi	
					Required	Available
1	N Main St @ Cutler Rd	50	48	820	1,250	3,500
2	Main St @ Princeton St	98	88	1,560	2,000	4,700
3/3A	Main St @ High St	88	85	1,500	5,000/2,000	8,100
4/4A	Reservoir St behind Holden Commons Plaza	80	75	1,280	4,500/3,500	4,900
5	Boyden St @ Woodland Rd.	85	74	1,190	3,000	3,100
6	Newell Rd. opp Winter Hill Rd.	122	120	1,810	750	adeq.
7/7A	Industrial Dr @ Main St	118	75	2,710	4,000/3,000	4,200
8	Shrewsbury St @ Main St	116	100	1,550	2,250	4,100
9	Shrewsbury St @ Chapel St	105	95	1,280	2,500	4,100
10	Bullard St @ Baptist Church	88	54	2,390	3,000	3,500
11	Wachusett St south of River St	80	76	2,380	2,000	10,300
12	Wachusett St @ Moscow Rd	37	30	980	750	1,600
13	Lovell Rd @ Greenwood Pkwy	84	70	1,210	1,000	2,700

Section 5
Distribution System Model

5.1 General

This section describes the development of the hydraulic model used to evaluate the water distribution system adequacy under existing and future 2030 water demand conditions. Data used to develop the model was provided by the Town and was based primarily on the existing water distribution system pipe schematic map. CDM conducted hydrant flow tests and C-value tests to calibrate the model to field conditions. The calibrated model was then verified by comparing model outputs to the Supervisory Control and Data Acquisition (SCADA) system data. The calibrated and validated model was used to identify water system deficiencies. The software used to simulate the water distribution system was WaterGEMS® Version 3.0 developed and distributed by Haestad Method, Inc. of Waterbury, Connecticut.

5.2 Hydraulic Model

A computer simulation model of Holden's water distribution system was developed to evaluate the system under existing and estimated future 2030 water demand conditions. WaterGEMS® Version 3.0, with an AutoCAD interface, was the modeling software used to perform the hydraulic analysis.

WaterGEMS is a fully interactive, multi-application software program for use in the comprehensive modeling of water distribution piping systems. WaterGEMS combines a powerful point and click interface for network construction, drawing, and database management; highly advanced and computationally efficient hydraulic and water quality simulation modules based on EPANET; and a complete graphical interface running within AutoCAD for Windows environment. The advantage of this feature is that maps can be displayed directly from AutoCAD with model results and produce easy to understand visual presentations.

The model network can be developed to precisely match actual system layout based on user-definable scales. The scenario manager capability allows development of multiple specific modeling scenarios for one water distribution model. The user can formulate and analyze numerous modeling alternatives based on different network conditions, demands, and operating scenarios. This helps in analyzing alternative recommendations and comparing the best alternative.

The model analyzes by balancing the volume of water entering a pipe junction with that leaving the junction and the demand on that junction. By an iterative process of balancing, each and every junction eventually results in pressure values and flows through each pipe.

5.3 Development of System Schematic

A system schematic is an illustration of the piping system in which pipes are represented as numbered 'links' and pipe intersections are represented as 'nodes.' Points of supply are also represented as numbered 'nodes.'

The original schematic of the Holden distribution system piping network was prepared in 1998 as part of the "Water System Reconfiguration Report." The preliminary source of data input was taken directly from a previous model generated by CH2M Hill for the Town of Holden in 1989. Data provided by the CH2M Hill model included water storage tank information, pipe diameter, pipe roughness coefficient (C-value), node elevation and node demand. However, the 1989 CH2M Hill model did not include the entire water distribution system. Therefore, the information provided in the 1989 CH2M Hill model was supplemented by Department of Public Works water main tie cards, record drawings, subdivision plans, pumping station data, past engineering reports, and other facilities information needed to accurately map and model Holden's water distribution system. The new node elevations were approximated using the most recent USGS topographic maps of the Town, at a scale of 1:25,000 and 3 meter contours. The USGS elevations were converted to feet by multiplying the metric elevation by 3.28 feet.

Selection of pipe roughness coefficient (C-value) and the distribution of water consumption in the model required additional work as described below.

5.4 Assigning Demands

The original demand allocation within the 1998 CDM model was based on the 1989 CH2M Hill model in which the node demand was assigned based on the ratio of service connections represented at a particular node to the total number of high service system connections.

As stated above, the 1989 CH2M Hill model did not cover the entire water distribution system; therefore, as part of the Water Distribution System Master Plan, new node demands were assigned. For the Low Service System, CDM assigned node demand based on the ratio of service connections represented by a particular node to the total number of service system connections. For the High and Super High Service System, CDM redistributed the node demand determined by CH2M Hill based on the ratio of service connections represented by the new node to the total number of service system connections.

Although the goal is to assign demands throughout the model as accurately as possible, water distribution models are not generally sensitive to demand allocation as compared to fire flow. As compared to high flow demands, such as hydrant flow tests, normal system conveyance of the low and widely distributed node demand result in only minimal pipeline flow velocities and headlosses. For this reason, simulated fire flows, which stress the system, tend to govern system calibration more than average demand conditions.

The current model base demand condition reflects 2000 average day demands. To obtain daily demand variations (i.e., maximum day, peak hour, etc.) or system demands under future conditions, a global peaking factor can be applied to each node demand. By multiplying all demands by an appropriate peaking factor, the base model demand can be globally increased or decreased to reflect the analysis conditions desired.

5.5 Pipe Friction Factors

The Hazen-Williams C-value is a relative measure of the hydraulic capacity of a water main. It can be estimated in the field by measuring the flow rate and corresponding headloss through a known length of pipe, and utilizing these values in the Hazen-Williams formula. At a constant flow rate, the smaller the value of C, the greater the drop in water pressure along a given length of main. For example, a 6-inch pipe having a C-value of 100 will transport over twice as much water, with the same pressure drop, as a 6-inch pipe of the same length with a C-value of 50. It should be noted that, in general, any obstruction, such as a partially closed valve, would reduce the C-value in what might otherwise be a high capacity main.

Holden's distribution system includes approximately 25-miles of cast iron water main, approximately 45-miles of asbestos cement water main and approximately 35-miles of ductile iron water main.

Holden installed unlined cast iron water mains until approximately 1950. Unlined cast iron water mains, especially when exposed to corrosive water over a number of years, will develop metallic salt deposits on the pipe interior. Accumulation of these deposits, or tubercles, has a two-fold effect on the hydraulic flow capacity: (1) it reduces the actual inside diameter of the main and hence the amount of water which the pipe can deliver; and, (2) it causes increased frictional headloss because of turbulence resulting from the roughness and unevenness of deposits. Within the model, C-values for unlined cast iron water mains were initially set between 60 and 80, depending on pipe diameter and age. During model calibration, C-values for unlined cast iron water mains were adjusted to between 40 and 70.

Asbestos cement water mains, even when exposed to corrosive water, will not tuberculate, which lent to the pipes popularity and use from 1950 through the 1970s. In fact, exposing asbestos cement to corrosive water may erode the pipe wall and increase the internal pipe diameter. Therefore, C-values for asbestos cement water main may increase slightly; even though structurally, the asbestos cement water main may become weaker. In the model, C-values for asbestos cement water mains were initially set between 120 and 130, depending on pipe diameter and age.

Since approximately 1980, Holden has been installing cement lined ductile iron water main. Unlike unlined cast iron water mains, cement lined ductile iron are more resistant to tuberculation. Initially within the model, C-values for cement lined ductile iron water main were set between 100 and 120, depending on pipe diameter and age.

Adjustments to these initial C-value assumptions were made during calibration.

5.6 Model Calibration

Model calibration generally involves simulating each hydrant flow test in the model; comparing the field results against model results; and making adjustments or corrections to the model, as required, to closely match the computed system response with actual field data.

In calibrating the model, the greatest variable is the C-value of unlined cast iron mains. The C-values of these mains are adjusted during calibration, such that the model simulates the stresses placed on the distribution system during hydrant flow testing. A model is generally considered calibrated when it is able to simulate pressure drop and flows within 10 percent of those measured in the field.

As discussed above, CDM developed a calibrated computer model of Holden's high service system in 1998 as part of the water distribution system reconfiguration evaluation. For more information regarding the original field testing and model calibration, see the "Final-Water System Reconfiguration Report" dated July 1998 (revised October 1998). This section of the report will focus on the field testing and calibration efforts performed to validate the previously calibrated high service system portion of the model and to calibrate the low service system portion of the water distribution model.

5.6.1 Hydrant Flow Tests

In April 1999, CDM and the Holden Water Department personnel performed a total of 10 hydrant flow tests. The locations of the tests are presented in Water Distribution System Map (appended) and the results of the tests are presented in Table 5-1. Hydrant flow test FF1-99 at the intersection of North Main Street and Millbrook Street was not performed, as the distribution system could not be modified to simulate the proposed option reconfiguration. In other words, Muschopauge Pond could not be taken off-line and the distribution system could not be modified to simulate the proposed "Option D" reconfiguration by opening the closed gate valve at the intersection of Broad Street/Main Street and the partially closed gate valve that controls flow from Muschopauge Pond at the intersection of Mill Brook Street/Main Street, therefore, hydrant flow test FF1-99 was not performed.

Overall, the purpose of the hydrant flow tests was to validate the previously calibrated high service system computer model and calibrate the low service system portion of the computer model. Test areas were selected based on system hydraulics and water distribution system facility locations. The test areas selected were located near water supply sources, water storage tanks, major water main intersections, water system extremities and other critical areas (i.e., schools).

Table 5-1
Hydrant Flow Test Data Summary

Test No.	Location	Gauge Hydrant Pressure (psi)		Flow Rate (gpm)	
		Static	Residual	Flow Tested	Flow at 20 psi
High Service System					
FF1-99	North Main St. & Millbrook St.	NA	NA	NA	NA
FF2-99	Jamieson Rd. & Walnut Terrace	62	37	1,460	1900
FF3-99	Somerset Lane and Colonial Dr.	104	25	730	800
FF4-99	256 Reservoir Street	57	45	2,540	4700
FF5-99	347 Bullard Street	80	43	2,490	3200
FF6-99	Shrewsbury St & Holden St.	104	50	2,570	3300
FF7-99	End of Shrewsbury Street	104	56	1,210	1600
FF8-99	Salisbury St. (Dawson School)	103	52	1,810	2400
Low Service System					
FF9-99	Wachusett St. and Union St.	93	68	2,630	4700
FF10-99	End of Fort Sumter Drive	51	28	1,430	1700
FF11-99	178 Mason Road	50	19	1,500	1500

Two or more hydrants were identified at each location; one hydrant was used to monitor the system pressure by attaching a pressure gauge to the 2 ½-inch port, and the other hydrant(s) was used to measure the flow. The purpose of the test was to measure the drop in system pressure at a specific hydrant flow rate. Both static pressures and residual pressures are shown in Table 5-1. Static pressures represent the system pressure prior to the flow test. Residual pressure was recorded during the flow test and represents the system pressure at a measured flow rate. A pressure drop of 10 psi or greater is recommended in order to ensure greater accuracy. If feasible, two or more hydrants were opened at once in order to obtain the desired pressure drop. In addition, pertinent data from the Town's water supply facilities, water storage tanks and water booster stations were gathered for the time period that the testing was performed.

The results of these hydrant flow tests were then used to calculate the flow rate that would be available from the system at the test location while maintaining a residual system pressure of 20 psi. This is the minimum system pressure used by ISO to calculate available fire flows at specific locations within a community. The reason for maintaining this residual pressure in the system during a fire is to sustain a water supply to area users and to provide adequate pressure for fire fighting equipment.

5.6.2 C-Value Tests

In addition to the hydrant flow tests, CDM and Holden Water Department personnel performed a total of six C-value tests throughout the system in April 1999. The results of the C-value tests are presented in Table 5-2. The purpose of the tests was to confirm the low C-values that were assigned to unlined cast iron water mains during the previous model (1998) calibration.

As required to perform accurate C-value tests, the pipe network was reviewed to maximize the pipe test section length and minimize inconvenience to consumers. Next, the hydrants to flow and gauge were determined as well as which valves needed to be closed to isolate the test section of pipe. The knowledge and input of Water Department personnel was heavily relied upon during this procedure. As a result, 5 test areas were selected to represent the different size, unlined cast iron water mains and one test area was selected to represent the asbestos cement water mains. The locations were:

- Main Street; 10-inch diameter unlined cast iron water main approximately 2,500-ft length from Bailey Road to Adams Street Booster Station.
- Shrewsbury Street; 10-inch diameter unlined cast iron water main approximately 1,750-ft length from Adams Street Booster Station to Holden Street.
- Shrewsbury Street; 8-inch diameter unlined cast iron water main approximately 1,050-ft length from Holden Street to Doyle Street.
- Chapel Road; 6-inch diameter asbestos cement water main approximately 900-ft length from Shrewsbury Street.
- Holden Street; 6-inch diameter unlined cast iron water main approximately 1,950-ft length from Shrewsbury Street to Brentwood Drive.
- Bailey Road; 6-inch diameter unlined cast iron water main approximately 1,400-ft length from Main Street to Dawson School Access Road.

All tests were conducted in April 1999 and the results are tabulated in Table 5-2. The results indicate that that the unlined cast iron water mains are heavily tuberculated and justified the use of low C-values in calibrating the model where required.

Table 5-2
C-Value Test Data Summary

Location	Pressure Drop Between Hydrants (ft)	Length Between Hydrants (ft)	Flow from Hydrant (gpm)	C-Value
Main Street – 10-inch diameter unlined cast iron water main from Bailey Road to Adams Street Booster Station				
Gauge A to B	9	1,460	680	88
Gauge B to C	19	1,040	680	49
Gauge A to C	28	2,500	680	64
Shrewsbury Street – 10-inch diameter unlined cast iron water main from Adams Street Booster Station to Holden Street				
Gauge A to B	8	750	505	47
Gauge B to C	6	1,000	505	67
Gauge A to C	14	1,750	505	56
Shrewsbury Street – 8-inch diameter unlined cast iron water main approximately 1,050-ft length from Holden Street to Doyle Street.				
Gauge A to B	28	1,050	590	62
Chapel Road – 6-inch diameter asbestos cement water main approximately 900-ft length from Shrewsbury Street				
Gauge A to B	19	900	480	121
Holden Street – 6-inch diameter unlined cast iron water main approximately 1,950-ft length from Shrewsbury Street to Brentwood Drive.				
Gauge A to B	116	1,950	300	44
Bailey Road – 6-inch diameter unlined cast iron water main approximately 1,400-ft length from Main Street to Dawson School Access Road.				
Gauge A to B	47	900	385	60
Gauge B to C	43	500	385	47
Gauge A to C	90	1,400	385	54

5.6.3 Calibration Methods

The actual system data obtained during the hydrant flow test program was used as criteria for calibration. Calibration involves simulating each hydrant flow test one at a time. For each test, the data collected from the Town's water distribution facilities were input into the model in order to simulate the hydraulic conditions in the system at the time of the hydrant flow test. The field test results were then compared to the model results. Adjustments and corrections were made to the model until the computed system response closely matched the actual field results. The most common adjustment needed was to decrease the C-values of the old, unlined cast iron water mains and to increase the C-values of the asbestos cement water mains.

5.6.4 Calibration Results

Calibration was performed by comparing the field measured static pressure and residual pressure drop at the hydrant flow test location with the predicted pressures. Pressures were also compared with field pressures at the various locations monitored during hydrant flow testing. C-values of the pipes were adjusted to achieve calibration to the hydrant flow tests. The model was considered to be calibrated when the residual pressure drops simulated on the computer model were within 10 percent of the actual field residual pressure drops. The results of calibration are presented in Table 5-3.

Table 5-3
Calibration Results Summary

Test No.	*Location*	*Gauge Hydrant Pressure (psi)*			*Calibrated?*
		Static	*Residual*	*Difference*	
FF1-99	North Main St. & Millbrook St.	NA	NA	NA	NA
	Model	NA	NA	NA	
FF2-99	Jamieson Rd. & Walnut Terrace	62	37	25	Yes
	Model	61	39	22	
FF3-99	Somerset Lane and Colonial Dr.	104	25	79	Yes
	Model	103	25	78	
FF4-99	256 Reservoir Street	57	45	12	Yes
	Model	57	45	12	
FF5-99	347 Bullard Street	80	43	37	Yes
	Model	82	42	40	
FF6-99	Shrewsbury St. & Holden St.	104	50	54	Yes
	Model	106	48	58	
FF7-99	End of Shrewsbury Street	104	56	48	Yes
	Model	106	54	52	
FF8-99	Salisbury St. (Dawson School)	103	52	51	Yes
	Model	101	53	48	
FF9-99	Wachusett St. and Union St.	93	68	25	Yes
	Model	93	69	24	
FF10-99	End of Fort Sumter Drive	51	28	23	Yes
	Model	50	25	25	
FF11-99	178 Mason Road	50	19	31	Yes
	Model	48	19	29	

Generally, most of the required adjustments to pipe C-values for calibration of the Holden water model are reasonable given the relative age and condition of the pipes; therefore, calibration was successful.

5.7 Model Validation

Calibration of the water distribution system model was completed in 1999, prior to implementing the "Option D" water distribution system reconfiguration recommendations and abandoning Muschopauge Pond. On October 17, 2001, the Town completed the necessary water distribution system reconfiguration improvements to discontinue use of Muschopauge Pond and place it on "emergency use" status. These water distribution system reconfiguration improvements included the construction of the 0.75 MG Jefferson Water Storage Tank, the modification of the Brattle Street interconnection and the installation of a town-wide SCADA system. The model validation process generally involved simulating the distribution system over a 24-hour period and comparing storage tank water level data from the SCADA system to the model results.

In January 2003, CDM downloaded hourly data from the SCADA system for 2002. By importing the Town's 2002 hourly SCADA system data into Microsoft Excel, CDM was able to reformat the data to calculate Holden's average, maximum and minimum day demands. In addition, CDM was able to develop the diurnal demand pattern or hourly demand for Holden's average, maximum and minimum days (see Table 5-4 and Figure 5-1). SCADA system data was not available yet for Holden's low service system groundwater supply wells; therefore, only SCADA system data for the Town's high and super high service systems were compared against the model results.

Once Holden's high/super high service system average, maximum and minimum day demands for 2002 were identified, the distribution system model was modified to simulate Holden's water supply facilities over these 24-hour periods. Included in these computer model simulations were Holden's average, maximum and minimum day diurnal demand patterns. Overall, the water levels within the storage tanks predicted by the calibrated water distribution system model were within 1-foot and well within 10 percent of the water level data from the SCADA system (see Figures 5-2 through 5-4). Therefore, there is a high level of confidence that the water distribution system model calibrated in 1998 can accurately represent the current reconfigured water distribution system.

Table 5-4
Diurnal Demand Pattern Multipliers

Time	***Min Day Demand Multiplier***	***Ave Day Demand Multiplier***	***Max Day Demand Multiplier***
6:00 AM	0.75	0.90	0.95
7:00 AM	2.00	1.72	1.65
8:00 AM	1.90	1.60	1.65
9:00 AM	1.45	1.28	1.40
10:00 AM	1.28	1.16	1.05
11:00 AM	1.17	1.12	0.98
12:00 PM	1.13	1.09	0.94
1:00 PM	1.10	1.07	0.90
2:00 PM	1.07	1.05	0.86
3:00 PM	1.06	1.04	0.83
4:00 PM	1.08	1.03	0.81
5:00 PM	1.15	1.07	0.82
6:00 PM	1.31	1.15	0.89
7:00 PM	1.45	1.37	1.02
8:00 PM	1.34	1.54	1.25
9:00 PM	1.10	1.44	1.68
10:00 PM	0.85	1.01	1.68
11:00 PM	0.65	0.75	1.16
12:00 AM	0.47	0.55	0.83
1:00 AM	0.35	0.40	0.60
2:00 AM	0.31	0.35	0.47
3:00 AM	0.30	0.35	0.44
4:00 AM	0.32	0.41	0.49
5:00 AM	0.41	0.55	0.65
6:00 AM	0.75	0.90	0.95

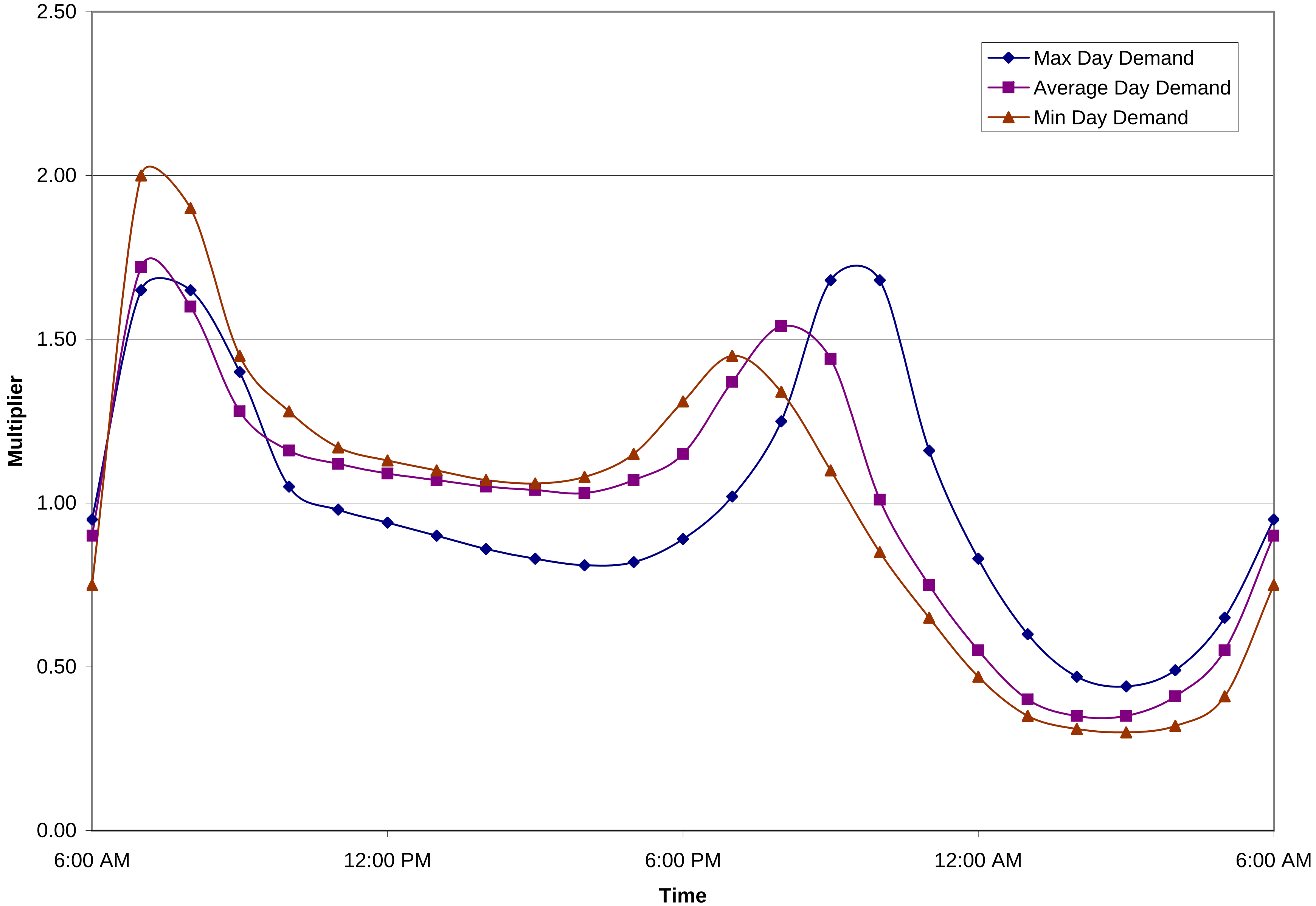
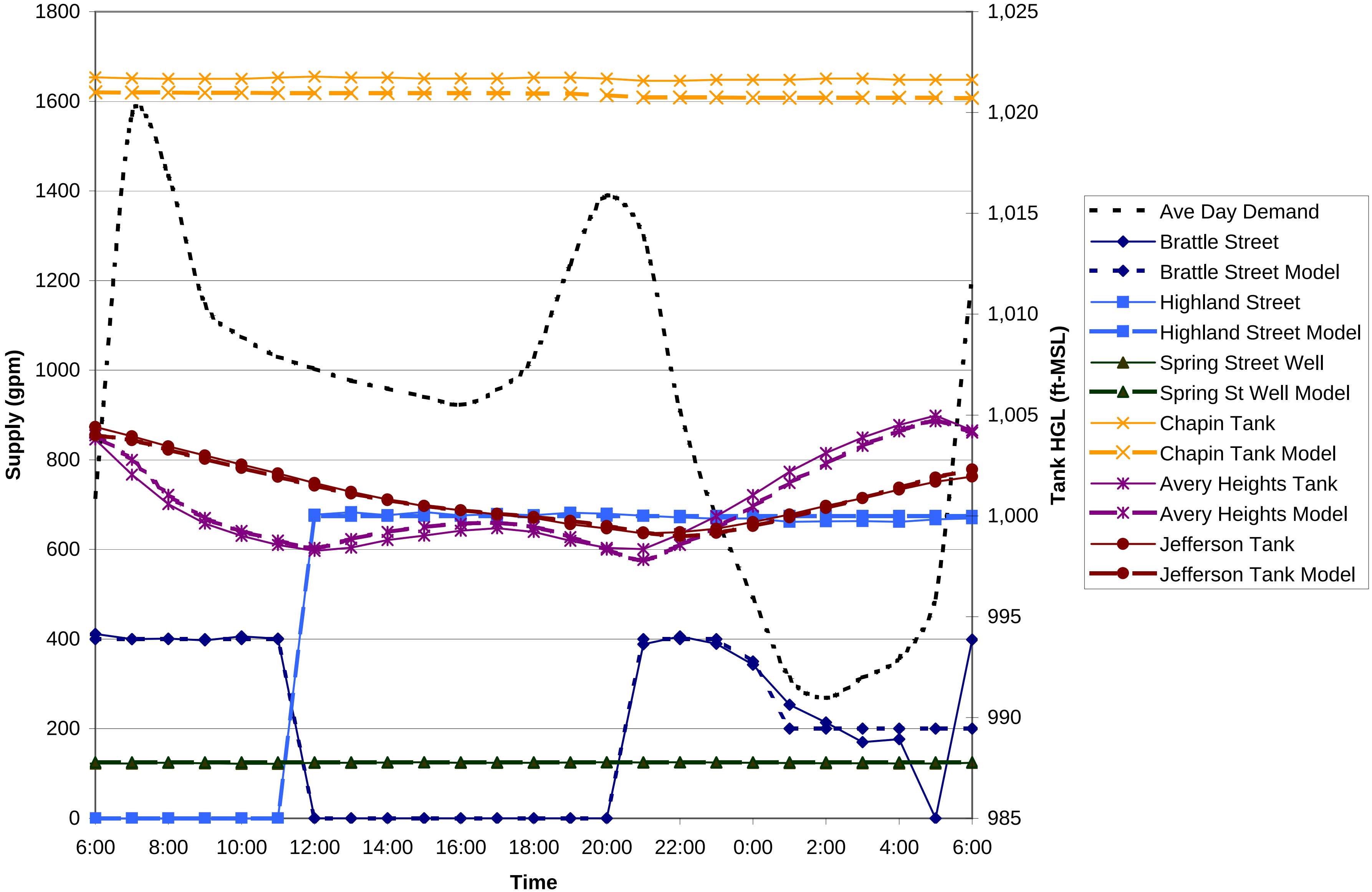


Figure 5-1
Diurnal Demand Patterns
Town of Holden, Massachusetts

CDM



CDM

Figure 5-2
Average Day Model Validation
Town of Holden, Massachusetts

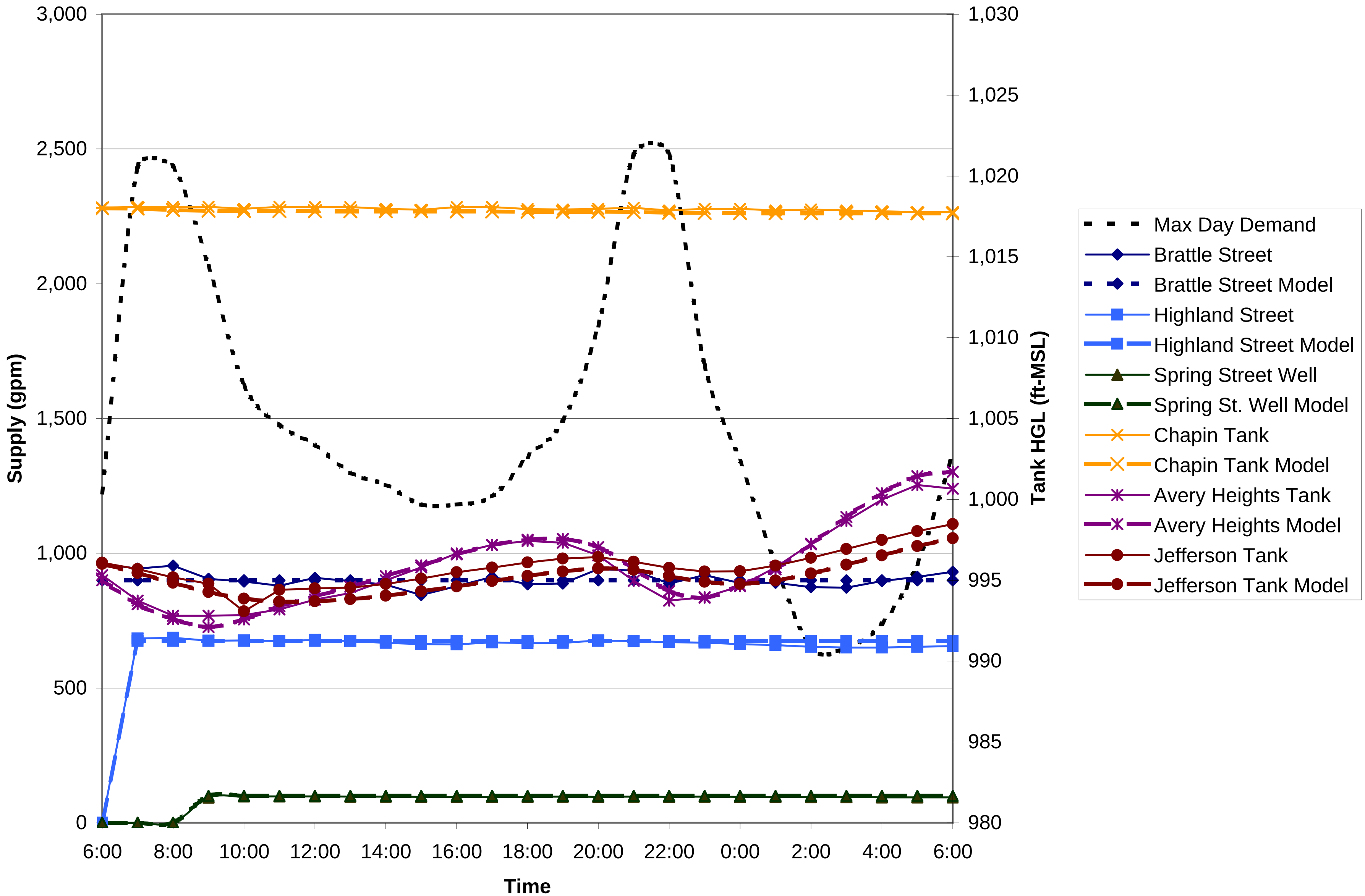
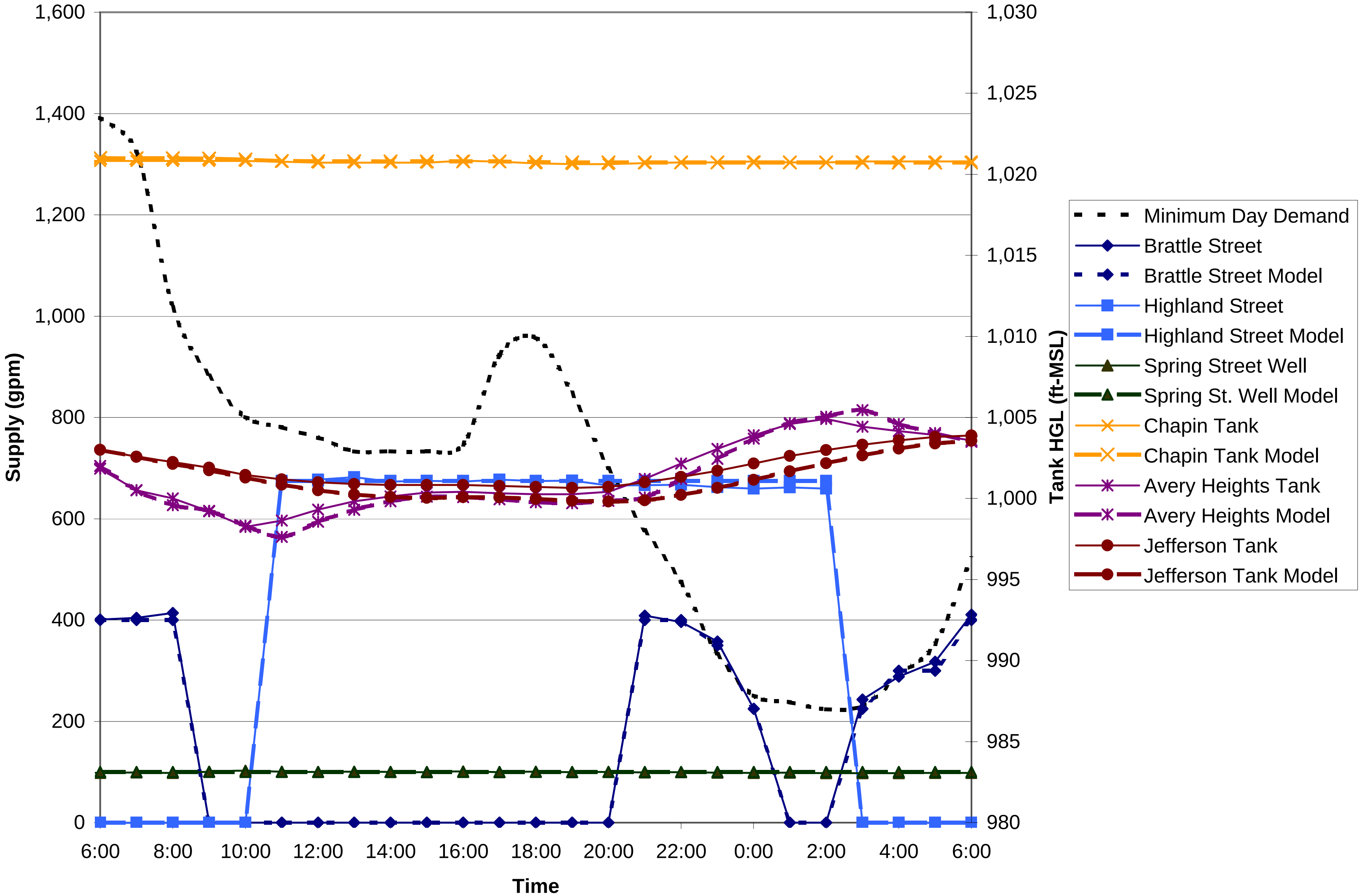


Figure 5-3
Maximum Day Model Validation
Town of Holden, Massachusetts

CDM



CDM

Figure 5-4
Minimum Day Model Validation
Town of Holden, Massachusetts

Section 6
Distribution System Evaluation

6.1 General

CDM evaluated Holden's piping, pumping and storage facilities to determine the adequacy of the existing water distribution system to meet future water demand conditions and provide fire protection. To evaluate Holden's existing water distribution system, system analysis criteria were established to set minimum requirements for service pressures and flow conditions. CDM analyzed Holden's existing water distribution system using the calibrated model developed for the project. Information regarding the water distribution system model development and calibration was presented in Section 5.

6.2 System Hydraulic Analysis Criteria

Holden's water system facilities (i.e., piping, pumping and storage facilities) were evaluated to determine the system's ability to meet the following conditions for the target year of 2030:

- Fire flow requirements during maximum day demand
- Peak hour during maximum day demand

6.2.1 Minimum System Pressures

According to the Massachusetts Department of Environmental Protection (MassDEP) 2001 Guidelines and Polices for Public Water Systems, the criteria for water main design is: "The system shall be designed to maintain a minimum pressure of 20 psi at ground level at all points in the distribution system under all operating conditions." This standard helps to avoid potential cross-connections and negative pressures (vacuum) that could occur at service connections (at high elevations) during fire flows or other significant demand events.

For this study, the desired minimum pressure during the peak hour demand period was 35 psi at ground elevation in all areas of the Town served by the water system. During a maximum day demand with a coincidental fire flow, the desired minimum pressure of 20 psi should be maintained throughout the system.

6.2.2 Maximum Velocities and Head Loss

According, to the American Water Works Association (AWWA) Manual of Water Supply Practices, "Computer Modeling of Water Distribution System" (AWWA M32, Second Edition, 2005), pipes are considered potentially deficient or limiting if they are predicted to have any of the following conditions:

- Velocities greater than 5 feet per second;

- Head losses greater than 6 feet per 1,000 feet in pipes with diameters less than 16 inches;

- Head losses greater than 2 feet per 1,000 feet in pipes with diameters 16-inch and greater.

These limits were used as a general indicator of potential problems and were not considered hard and fast rules. The ultimate test of the adequacy of a water main is the pressure that is provided at the delivery point in order to meet the required Insurance Services Office (ISO) fire flow rate.

6.2.3 Fire Flow Requirements

The ability of the distribution system to provide adequate flow during fires was evaluated based on fire flow requirements established for the Town by the Insurance Services Office (ISO). The ISO is an independent organization that compiles data that are used to establish rates for fire protection policies for both residential and commercial buildings. ISO established fireflow requirements for the Holden water system in 2003. CDM adapted the fire flow requirements listed in Table 6-1 from the 2003 ISO Public Protection Classification Survey for the Town of Holden. Section 4 of this report has gone into further detail about ISO methodology and flow requirements in Holden.

Table 6-1
2003 ISO Fire Flow Test Data Summary

Test No.	Location	Gauge Hydrant Pressure (psi)		Flow Rate (gpm)		
		Static	Residual	Flow Tested	Flow at 20 psi	
					Required	Available
1	N Main St @ Cutler Rd	50	48	820	1,250	3,500
2	Main St @ Princeton St	98	88	1,560	2,000	4,700
3/3A	Main St @ High St	88	85	1,500	5,000/2,000	8,100
4/4A	Reservoir St behind Holden Commons Plaza	80	75	1,280	4,500/3,500	4,900
5	Boyden St @ Woodland Rd.	85	74	1,190	3,000	3,100
6	Newell Rd. opp Winter Hill Rd.	122	120	1,810	750	adeq.
7/7A	Industrial Dr @ Main St	118	75	2,710	4,000/3,000	4,200
8	Shrewsbury St @ Main St	116	100	1,550	2,250	4,100
9	Shrewsbury St @ Chapel St	105	95	1,280	2,500	4,100
10	Bullard St @ Baptist Church	88	54	2,390	3,000	3,500
11	Wachusett St south of River St	80	76	2,380	2,000	10,300
12	Wachusett St @ Moscow Rd	37	30	980	750	1,600
13	Lovell Rd @ Greenwood Pkwy	84	70	1,210	1,000	2,700

6.3 Distribution System Storage Analysis

There are several reasons for providing storage within a distribution system:

- Storage helps dampen hourly demand fluctuations that otherwise would need to be met by supply sources, thereby reducing operating costs.
- Storage helps the system meet required fire flow; thus, reducing pumping capacity (and cost) at supply sources, as well as reducing piping capacity requirements.
- Storage provides a volume of water for emergencies in case of pipeline breaks, mechanical equipment malfunctions, or power failure.
- Storage, when properly located, helps to equalize pressure throughout the distribution system, to provide pressure surge relief, and to help control pumping operations.

In systems providing adequate storage, water supply pumping facilities should be sized to provide maximum day demand. During periods when system demands are greater than maximum day (i.e., peak hour demand conditions), these demands are met by active storage (equalization storage). Storage facilities are also sized to provide fire protection volume.

The basis for these storage requirements is summarized below:

- ***Equalization Storage:*** The total volume required to meet hourly demand, which exceeds the maximum day demand. Equalization storage volume can be estimated either based on existing records or based on literature values obtained in similar communities.
- ***Fire Protection Storage:*** The total volume of water required to provide fire protection. To determine this volume, the maximum fire flow required is selected along with the appropriate duration (typically 2 or 3 hours).
- ***Emergency Storage:*** The volume of storage allocated in case of a power failure, pipeline break, or equipment malfunction. The amount of emergency storage is a policy decision based on an assessment of the risk of failure and the desired degree of system dependability. In most cases, if a community has an adequate emergency standby power source at its water supply, emergency storage is considered to be a lower priority requirement.

6.3.1 Active Storage Requirements

Distribution system storage facilities are considered adequate if the existing active storage volume meets equalization and fire protection requirements for the community. Active storage is determined by local topography and represents the volume of water in storage that provides a minimum acceptable pressure (e.g., 35 psi during peak hour conditions or 20 psi during fire flow conditions) at the highest service elevation in the distribution system. This analysis is initially performed using static pressures and elevations, but verified under dynamic conditions using the computer model.

6.3.2 Analysis of Existing Storage

As discussed in Section 2, the Town of Holden's water distribution system is divided into two major pressure zones: the low service system and high service system. Even though water is pumped from the low service system to the high service system (via the Highland Street Booster Station) and water can be supplied from the high service system to the low service system (by manually opening gate valves), to be conservative, CDM considers these service systems to be independent of each other for this storage analysis.

There are also three super high service systems in Holden. These super high service system areas are small and supplied from the high service system; therefore, these systems are considered extensions of the high service system for the purpose of this storage analysis. The Chapin Road Tank water is available to the high service system through the existing valving and control facilities. Therefore, the Chapin Road Tank is considered part of the high service system for the purpose of this storage analysis.

Low Service System – Available Active Storage

Holden has one tank available to meet the storage requirements for the low service system. The Highland Street Reservoir is a reinforced concrete tank located on Highland Street (Route 31). The tank has an original capacity of 2.0 MG and an overflow elevation of 806-feet MSL. In May 1983, the tank suffered a catastrophic failure and released approximately 2.0 MG of water. The tank was subsequently rebuilt and put back on-line in November 1986. However, because of the 1983 failure, the Town currently limits water level within the tank to an overflow elevation of 801-feet MSL, which results in a total capacity of approximately 1.5 MG over an 18-foot water height.

In general, the high elevation area in the low service system is located in the Nottingham Circle Area with an elevation of 715-feet MSL. The high elevation area around the Highland Street Reservoir is not included because the homes in this area are supplied by the high service system. The active storage water level required to maintain a static water pressure of 35 psi and 20 psi in the Nottingham Circle Area is 796-feet MSL and 761-feet MSL, respectively. This results in an equalization storage volume of 0.42 MG and a fire protection volume of 1.08 MG. It is important to note that the active storage water level required to maintain a static water pressure of 20 psi in the Nottingham Circle Area is below the base of the Highland Street Reservoir. Therefore, the fire protection volume was assumed to be the difference between the equalization storage volume and 783-feet MSL, which is the base of the Highland Street Reservoir. Table 6-2 summarizes the storage for the low service system.

Table 6-2
Active Storage Volume Analysis

	Low Service System	***High/Super High Service System***
Average Day Demand (Projected 2030)	0.17 MGD	1.78 MGD
Maximum Day Demand (Projected 2030)	0.34 MGD	3.56 MGD
Available Equalization Storage		
Highland Street Reservoir	0.42 MG	-
Jefferson Tank	-	0.35 MG
Avery Heights Tank	-	0.17 MG
Chapin Road Tank	-	1.56 MG
Total	**0.42 MG**	**2.08 MG**
Required Equalization Storage		
Based on Diurnal Curve	0.05 MG	0.53 MG
Based on Storage Volume Curves	0.08 MG	0.71 MG
Equalization Storage Surplus/(Deficit)	**0.34 MG**	**1.37 MG**
Available Fire Protection Storage		
Highland Street Reservoir	1.08 MG	-
Jefferson Tank	-	0.40 MG
Avery Heights Tank	-	0.15 MG
Chapin Road Tank	-	0.44 MG
Total	**1.08 MG**	**0.99 MG**
Required Fire Protection Storage		
Based on 2,000 gpm for 2 hrs Fire Flow	0.24 MG	-
Based on 3,500 gpm for 3 hrs Fire Flow	-	0.63 MG
Fire Protection Storage Surplus/(Deficit)	**0.84 MG**	**0.36 MG**
Total Active Storage Surplus/(Deficit)	**1.18 MG**	**1.73 MG**

Low Service System – Required Active Storage

Using the diurnal curve developed for the Town of Holden (see Section 5.7), the total equalization volume required for hourly fluctuation during the projected 2030 maximum day demand for the low service system is 0.05 MG (see Figure 6-1). To be conservative, CDM did not subtract the volume below the projected 2030 maximum day demand line between the two high demand peaks. CDM also compared the calculated equalization volume to standard hourly fluctuation storage volume curves based on a simulated demand sine wave and flow information from the Merrimack Curves, which is the "Relation of Extreme Discharge on Maximum and Minimum Days to the Average Daily Discharge of Domestic Sewage" for Merrimack Valley communities. According to the standard hourly fluctuation storage curve, the estimated equalization volume is 24 percent of projected 2030 maximum day demand for the low service system or 0.08 MG. The larger figure is utilized herein after to be

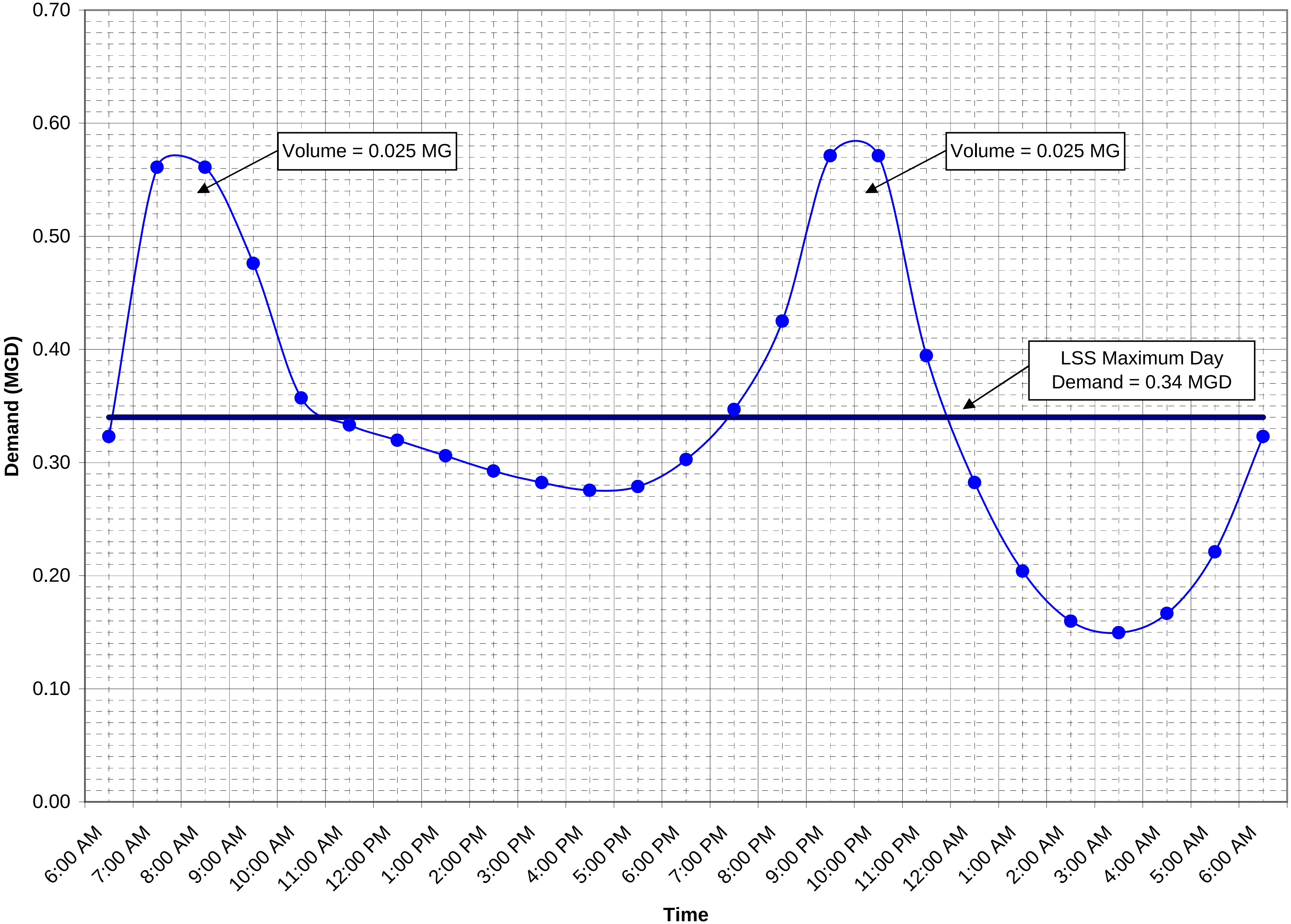


Figure 6-1
Low Service System
2030 Hourly Demand on Maximum Day
Holden, Massachusetts

conservative. According to the 2003 ISO Public Protection Classification Survey for the Town of Holden, the largest fire flow requirement for the low service system is 2,000 gpm at Wachusett Street south of River Street. Therefore, the required fire protection storage is 0.24 MG (i.e, 2,000 gpm for 2 hours).

Low Service System – Active Storage Conclusion

Based on the information presented above and indicated in Table 6-2, the Town has a surplus of both equalization storage volume and fire protection volume within the low service system. This results in an active storage surplus of 1.18 MG for the low service system.

High/Super High Service System – Available Active Storage

Holden has three tanks available to meet the storage requirements for the high and super high service systems:

Avery Heights Standpipe - The Avery Heights standpipe is a welded steel water storage tank located near Holden Center. The tank capacity is 1.0 MG over 52-feet, with an overflow elevation of 1,010-feet MSL.

Jefferson Reservoir - The Jefferson Water Storage Tank is a welded steel water storage tank located in the northwest Holden near Muschopauge Pond. The tank capacity is 0.75 MG over 15-feet, with an overflow elevation of 1008-feet MSL.

Chapin Road Reservoir - The Chapin Road Tank is a welded steel water storage tank located off Sycamore Drive. The tank has a capacity of 2.0 MG over 32-feet and an overflow elevation of 1026 feet MSL.

In general, the high elevation area in the high service system is located at the intersection of Millbrook Street and North Main Street with an elevation of 920-feet MSL. Similarly, the high elevation area in the Chapin Road Tank super high service system is located at the intersection of Chapin Road Tank Access Road and Sycamore Drive with an elevation of 920-feet MSL.

The high elevation areas around the Avery Heights and Jefferson Water Storage Tanks are not included in this analysis. Domestic water and fire protection for homes in the Avery Heights Tank area are supplied by the Morgan Circle Booster Station. Domestic water for homes in the Jefferson Storage Tank area is supplied by individual home booster pumps. The 20 psi requirement for fire protection in Jefferson Storage Tank area was neglected because there is sufficient water available from the high/super high service system storage tanks to supply this small residential area with fire flow protection.

The active storage water level required to maintain a static water pressure of 35 psi and 20 psi in both the high service system and the Chapin Road Tank super high service system are 1001-feet MSL and 966-feet MSL, respectively. This results in an equalization storage volume of 2.08 MG and a fire protection volume of 0.99 MG.

The active storage water level required to maintain a static water pressure of 20 psi in the high service system is below the base of the Jefferson Tank. Therefore, the fire protection volume was assumed to be the difference between the equalization storage volume and 993-feet MSL, which is the base elevation of the Jefferson Storage Tank. Similarly, the active storage water level required to maintain a static water pressure of 20 psi in the Chapin Road Tank super high service system is below the base of the Chapin Road Tank. Therefore, the fire protection volume was assumed to be the difference between the equalization storage volume and 994-feet MSL, which is the base of the Chapin Road Tank. Table 6-2 summarizes the storage for the high/super high service system.

High/Super High Service System – Required Active Storage

Using the diurnal curve developed for the Town of Holden (see Section 5.7), the total equalization volume required for hourly fluctuation during the projected 2030 maximum day demand for the high/super high service systems is 0.53 MG (see Figure 6-2). To be conservative, CDM again did not subtract the volume below the projected 2030 maximum day demand line between the two high demand peaks. CDM also compared the calculated equalization volume to standard hourly fluctuation storage curves based on a simulated demand sine wave and flow information from the Merrimack Curves, which is the “Relation of Extreme Discharge on Maximum and Minimum Days to the Average Daily Discharge of Domestic Sewage” for Merrimack Valley communities. According to the standard hourly fluctuation storage curve, the estimated equalization volume is 20 percent of projected 2030 maximum day demand for the high/super high service system or 0.71 MG. The larger figure is utilized hereafter, to be conservative.

According to the 2003 ISO Public Protection Classification Survey for the Town of Holden, the largest fire flow requirement for the high/super high service systems is 5,000 gpm on Main Street at the intersection of High Street. However, as stated in Section 4.3, a water system in general is only required to deliver a fire flow up to 3,500 gpm at a 20 psi residual pressure to obtain the best overall citywide insurance rating. Therefore, the maximum fire flow required to be provided by Holden in the high/super high service system is 3,500 gpm for 3 hours for a required fire protection storage of 0.63 MG.

High/Super Service Systems – Active Storage Conclusion

Based on the information presented above and indicated in Table 6-2, the Town has a surplus of both equalization storage volume and fire protection volume within the high/super high service systems. This results in an active storage surplus of 1.73 MG for the high/super high service systems.

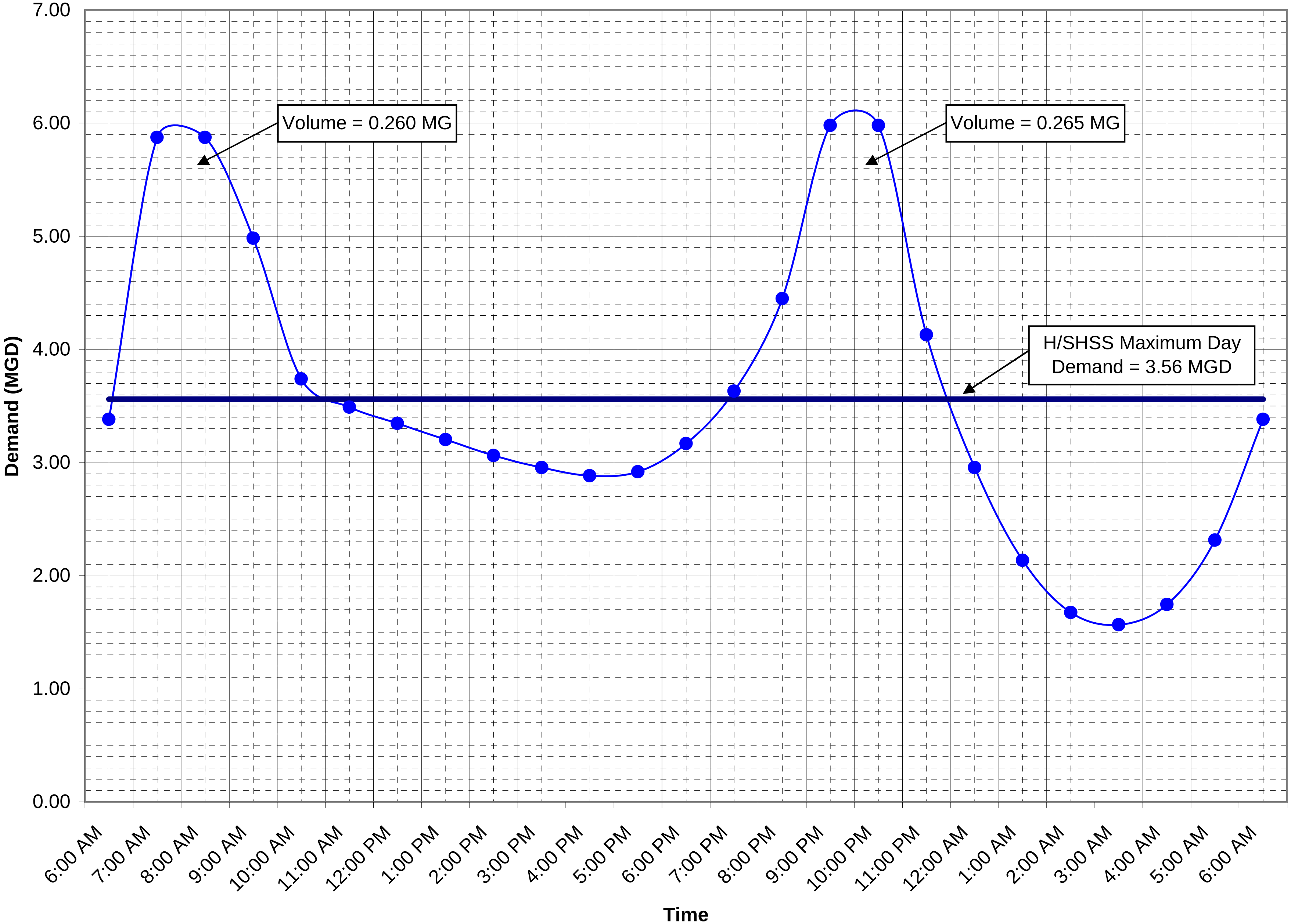


Figure 6-2
High/Super High Service System
2030 Hourly Demand on Maximum Day
Holden, Massachusetts

6.3.3 Available Emergency Storage

Since the calculated active storage volumes for equalization and fire protection were limited to the bottom of the storage tanks, the available emergency storage is assumed to be the calculated active storage surplus listed in Table 6-2. Therefore, the amount of water available for an emergency is 1.18 MG for the low service system and 1.73 MG for the high/super high service system for a town-wide total volume of 2.91 MG.

6.3.4 Distribution System Storage Analysis Results

Based on the information presented above and indicated in Table 6-2, the town will maintain an active storage surplus of 1.18 MG for the low service system and 1.73 MG for the high/super high service system for the target year of 2030. This active storage volume surplus of 2.91 MG can be used during an emergency. CDM will determine the need for emergency storage as part of the system reliability analysis performed in Section 6.4.

It is also important to note, that the high/super high service systems appear to have sufficient fire protection storage because the high/super high service systems have multiple tanks. Since no single tank has sufficient fire protection storage and since a fire can occur closer to one particular tank, CDM will further analyze the ability of the piping network to allow fire protection to be supplied from multiple tanks as part of the piping system analysis in Section 6.5.

6.4 Distribution System Reliability Analysis

As stated above, the Town of Holden has adequate storage volume to meet peak hour demands and fire protection supply. This evaluation will determine if Holden has sufficient water facility redundancy to supply maximum day demand under various emergency conditions. Emergency conditions include equipment malfunctions, pipeline break, or power failure.

CDM adopted the typical daily withdrawal volume for the in-town groundwater wells (without Mason Road Wellfield) and the intermunicipal agreement volume for the interconnection facilities listed in Table 6-3 as the water facility capacities used in the distribution system reliability evaluation. CDM also adopted the maximum supply from the low service system to the high service system based on the pump capacity of the Highland Street Booster Station.

6.4.1 Mechanical Failure Analysis

The Town of Holden currently operates four groundwater wellfields (Spring Street Well, Quinapoxet Wellfield, Mill Street Wellfield and Mason Road Wellfield). In the future, the Town is considering abandoning or placing the Mason Road Wellfield into “active-standby” status. If the Mason Road Wellfield is placed into “active-standby” status, all water quality testing would be kept up to date for the wellfield, but the wellfield would only be used on an intermittent or standby basis. Overall, even though the wellfield facilities do not include redundant pumping systems (i.e., 1 duty and 1 standby well pump), it is highly unlikely that the Town will experience mechanical failures at multiple wellfields simultaneously.

Table 6-3
Water Facility Capacities

In-Town Groundwater Wells	***MassDEP Approved Maximum Daily Volume [2]***	***Typical Daily Withdrawal***
Spring Street Well	0.20 MGD	0.15 MGD
Quinapoxet Wellfield	0.74 MGD	0.50 MGD
Mill Street Wellfield	0.30 MGD	0.25 MGD
Mason Road Wellfield [1]	0.16 MGD	0.10 MGD
Total In-Town Groundwater Supply	**1.40 MGD**	**1.00 MGD**
Total In-Town Groundwater Supply (w/o Mason Road Wellfield)	**1.24 MGD**	**0.90 MGD [1]**

Worcester Interconnection Facilities	***Interbasin Transfer Act Limit***	***Intermunicipal Agreement Limit***
Brattle Street Interconnection Valve Vault	1.00 MGD	1.00 MGD
Salisbury Street Interconnection Booster Station	2.10 MGD	2.10 MGD
Total Interconnection Supply	**3.10 MGD**	**3.10 MGD**

Low Service System Supply to High Service System	***Maximum Supply Based on Pump Capacity***
Highland Street Booster Station	1.00 MGD

Note: 1. The Town is considering abandoning or placing the Mason Road Wellfield onto Active Standby Status
2. MassDEP approved maximum daily volume from the Town's Water Management Act (WMA) permit; based on each Well's Zone II delineation. Currently, only Spring Street Well has such a limit in the Town's WMA permit; the others wells are expected to be added upon Zone II completion and approval

The Highland Street Booster Station (1 duty and 1 standby pump) and the Salisbury Street Interconnection Booster Station (2 duty and 1 standby pump) both include adequately designed redundant pumping systems. The Brattle Street Interconnection Valve Vault does not include a redundant valve, but the facility does have a bypass, which could be used in the event of a mechanical failure.

For this analysis, CDM assumed that both Quinapoxet Wells (the largest in-town supply source) were off-line as a result of mechanical equipment failure or groundwater contamination (see Table 6-4). Based on the analysis, the Town appears to have adequate short-term protection against mechanical failures or groundwater contamination even without the Mason Road Wellfield. However, long-term, the Town would need to consider re-activating the Mason Road Wellfield and/or implementing town-wide water conservation measures.

Table 6-4
Mechanical Failure Analysis

Low Service System	*Demand/Supply*	*Comments*
Demand:	**0.34 MGD**	**Maximum Day Demand (2030)**
Supply:		
Quinapoxet Wellfield	0.00 MGD	Assumed both wells offline due to mechanical failure or groundwater contamination.
Mill Street Wellfield	0.25 MGD	On-line
Mason Road Wellfield	0.00 MGD	Off-line/Placed into Active Standby Status
Total Low System Supply:	**0.25 MGD**	Low Service System needs 0.09 MG from storage and the system has 1.18 MG in active storage surplus.
Low Service System Adequately Protected?		**Yes**

High/Super High System	*Demand/Supply*	*Comments*
Demand:	**3.56 MGD**	**Maximum Day Demand (2030)**
Supply:		
Highland Street Booster Station	0.00 MGD	Assumed off-line [1]
Spring Street Wellfield	0.15 MGD	On-line
Brattle Street Interconnection	1.00 MGD	On-line
Salisbury Street Interconnection	2.10 MGD	On-line
Total High/Super High System Supply:	**3.25 MGD**	High/Super High System needs 0.31 MG from storage and system has 1.73 MG in active storage surplus.
High/Super High Service System Adequately Protected?		**Yes**

Note: 1. In the event of groundwater contamination at the Quinapoxet Wellfield, to be conservative, assumed the Highland Street Booster Station is off-line based on the time required to address this issue.

6.4.2 Major Water Main Failure Analysis

The low service system essentially has one major water main that connects the low service system wellfields to the Highland Street Tank. For example, if a water main break were to occur along Wachusett Street, then the northern part of the low service system could be without water. One option for the Town would be to install temporary over-land water mains from hydrant-to-hydrant around the water main break. A second option would be to operate the Mason Road Wellfield without the Highland Street Tank by opening a hydrant in the isolated area to prevent the isolated area from being over-pressurized by the well pump. Overall, based on the size of the low service system, the installation of water mains to better loop the Wachusett area is not necessary considering that all the major water mains in the low service system are located within road right-of-ways and are therefore easily accessible and quickly repairable.

For the most part, the major water mains within the high service systems are adequately looped such that a major water main failure would not significantly impact the system. There is one exception, the 24-inch suction side transmission main that connects the Salisbury Street Interconnection Booster Station to Worcester's high service system. Any water main break of this transmission main would require immediate repair in accordance with the intermunicipal agreement.

For this analysis, CDM assumed that the Salisbury Street Interconnection Booster Station is off-line as a result of a water main failure to the transmission main (see Table 6-5). Based on the analysis, the Town appears to be adequately protected against water main failures even without the Mason Road Wellfield. However, long-term, the Town would need to consider re-activating the Mason Road Wellfield and/or implementing town-wide water conservation measures.

6.4.3 Power Failure Analysis

Currently, the Town of Holden has emergency standby power at the Quinapoxet Wellfield and the Highland Street Booster Station. The Town also has the ability to connect a portable generator to the Salisbury Street Interconnection Booster Station, but the town does not own a portable generator. There is also no standby power at the Brattle Street Interconnection Valve Vault, but should a power failure occur, the operation of the valve will be controlled by a back-up pressure regulating pilot. Therefore, the valve can operate during a power failure and the Town can manually control the pressure at the valve vault by adjusting the back-up pressure regulating pilot setting. The Town would not be able to operate the flow metering equipment or the fluoride system at Brattle Street during a power failure.

For this analysis, CDM assumed only the Quinapoxet Wells, Highland Street Booster Station and the Brattle Street Interconnection Valve Vault are available during a town-wide power failure (see Table 6-6). Based on this extremely conservative analysis, the Town appears to be adequately protected against power failure and meets the standby power requirements as stated in the MassDEP 2001 Guidelines and Policies for Public Water System.

The Town might consider purchasing a portable standby generator for the Brattle Street Valve Vault to operate the facility fully during an emergency power failure. In a prolonged power failure, the Town may need to rent a portable generator to operate the Salisbury Street Interconnection Booster Station and/or implement town-wide water conservation measures.

Table 6-5
Water Main Break Analysis

Low Service System	*Demand/Supply*	*Comments*
Demand:	**0.34 MGD**	**Maximum Day Demand (2030)**
Supply:		
Quinapoxet Wellfield	0.50 MGD	On-Line
Mill Street Wellfield	0.25 MGD	On-Line
Mason Road Wellfield	0.00 MGD	Off-line/Placed into Active Standby Status
Total Low System Supply:	**0.75 MGD**	Low Service System can supply 0.41 MGD plus active storage surplus 1.18 MG to High System, but limited by Highland Street Booster Station capacity.[1]
Low Service System Adequately Protected?		**Yes**

High/Super High System	*Demand/Supply*	*Comments*
Demand:	**3.56 MGD**	**Maximum Day Demand (2030)**
Supply:		
Highland Street Booster Station[1]	1.00 MGD	On-line
Spring Street Wellfield	0.15 MGD	On-line
Brattle Street Interconnection	1.00 MGD	On-line
Salisbury Street Interconnection	0.00 MGD	Assume 24-inch Transmission Main Break
Total High/Super High System Supply:	**2.15 MGD**	High/Super High System needs 1.41 MG from storage and system has 1.73 MG in active storage surplus.
High/Super High Service System Adequately Protected?		**Yes**

Note: 1. The amount of water available from the low service system to high service system is 1.59 MG, however, the amount of water supplied from the low service system to high service system is limited by the capacity of the Highland Street Booster Station.

Table 6-6
Power Failure Analysis

Low Service System	*Demand/Supply*	*Comments*
Demand:	**0.34 MGD**	**Maximum Day Demand (2030)**
Supply:		
Quinapoxet Wellfield	0.50 MGD	Standby Power Available
Mill Street Wellfield	0.00 MGD	No Standby Power Available
Mason Road Wellfield	0.00 MGD	Offline/Placed into Active Standby Status
Total Low System Supply:	**0.50 MGD**	Low Service System can supply 0.16 MGD plus active storage surplus 1.18 MG to High System, but limited by Highland Street Booster Station capacity.[1]
Low Service System Adequately Protected?		**Yes**

High/Super High System	*Demand/Supply*	*Comments*
Demand:	**3.56 MGD**	**Maximum Day Demand (2030)**
Supply:		
Highland Street Booster Station [1]	1.00 MGD	Standby Power Available
Spring Street Wellfield	0.00 MGD	No Standby Power Available
Brattle Street Interconnection	1.00 MGD	No Standby Power Available. However, the valve is equipped with a back-up pressure regulating pilot that would operate the valve without the fluoride system.
Salisbury Street Interconnection	0.00 MGD	No Standby Power Available
Total High/Super High System Supply:	**2.00 MGD**	High/Super High System needs 1.56 MG from storage and system has 1.73 MG in active storage surplus.
High/Super High Service System Adequately Protected?		**Yes**

Note: 1. The amount of water available from the low service system to high service system is 1.34 MG, however, the amount of water supplied from the low service system to high service system is limited by the capacity of the Highland Street Booster Station.

6.5 Piping System Analysis

Using the computer model, CDM analyzed Holden's water distribution system according to the design criteria discussed below. The conditions evaluated were:

- ***Maximum Day Demand plus Fire Flow*** – This analysis evaluated the distribution system's ability to meet maximum day demands with a coincidental fire flow. Under these simulations, system demands equaled maximum day demands, the tank levels corresponded to those after 100 percent of the required equalization volume was withdrawn and the supply sources were providing maximum day flow. The minimum acceptable residual pressure was 20 psi.

- ***Peak Hour Demand*** – This analysis evaluated the distribution system's ability to meet peak hour demands. Under this simulation, system demands equaled peak hour demands, the tank levels corresponded to those after approximately 100 percent of the required equalization volume was withdrawn and the supply sources were providing maximum day flows. The minimum acceptable residual pressure was 35 psi.

CDM also noted water mains that were considered potentially deficient or limiting if they were predicted to have high velocities or high headlosses as described in Section 6.2.2.

6.5.1 Maximum Day plus Fire Flow Evaluation

The ability of Holden's distribution system to provide adequate fire protection was based on the system's ability to provide the required fire flows established by ISO. The 2003 ISO fire flow requirements, shown in Table 6-1, were used to analyze the capacity of Holden's water system facilities.

Extended period model simulations were conducted to evaluate the distribution system's capacity to meet 2030 maximum day demand plus coincidental ISO fire flows. As stated in Section 6.3, the high/super high service systems appear to have sufficient fire protection storage because the system has multiple tanks. Since no single tank in the high/super high service systems has sufficient fire protection storage and since a fire can occur closer to one particular tank, these extended period model simulations will determine if the piping network is sufficient for fire protection to be supplied from the multiple tanks.

Fire flows were simulated separately at each of the locations identified in the ISO report for the durations listed in Table 6-7. Each simulation was evaluated based on the criteria established above: (1) the ability to provide the required fire flow under maximum day demand conditions; and, (2) maintain a minimum residual system pressure of 20 psi.

Table 6-7
ISO Required Fire Flow Duration

Required Fire Flow	Duration
2,500 gpm or less	2 hours
3,000 to 3,500 gpm	3 hours

According to the model, the water distribution system was able to provide the required fire flows under projected 2030 demands at all the locations listed in Table 6-1, with the exception of Boyden Street at Woodland Road. The system was unable to provide 3,000 gpm of fire flow at the intersection of Boyden Street and Woodland Road under projected 2030 maximum day demands. Based on the 2003 ISO Fire Flow Test Data, this area had 3,100 gpm of available fire flow, but the projected fire flow deficiency is primarily a result of the projected system demand increase. The available fire flow is also affected by the presence of 6-inch unlined cast iron water mains on Boyden Street at Woodland Road, which is recommended for upgrade (see Section 6.5.3).

Despite this one problem area, a comparison of the 1991 ISO Fire Flow Test Data to the 2003 ISO Fire Flow Test Data (see Section 4.4), illustrates that the town's "Option D" water system improvements have helped to improve the overall capacity of the distribution system to meet fire flow requirements.

6.5.2 Peak Hour Evaluation

Simulations were conducted to evaluate the system's ability to meet 2030 peak hour demands. The analyses showed that the system can meet these demands while maintaining a residual of 35 psi or greater throughout the system, with the exception of the areas immediately surrounding the water storage tanks. These areas nevertheless are adequate, for reasons discussed below.

- ***Highland Street Tank*** – The homes surrounding the Highland Street Tank are supplied from a high service system water main.

- ***Jefferson Tank*** – Two homes surrounding the Jefferson Tanks are equipped with individual home booster pumps. Individual home booster pumps were provided to 199 Muschopauge Road and 100 Millbrook Street by the Town as part of the "Option D" implementation.

- ***Avery Heights Tank*** – The homes surrounding the Avery Heights Tanks are supplied from the Morningside Development super high system via the Morgan Circle Booster Station.

- ***Chapin Road Tank*** – There are currently no homes immediately surrounding the Chapin Road Tank.

If additional homes were to be built near the Jefferson Tank (i.e., Muschopauge Road and Millbrook Street) or if homes were to be built near the Chapin Road Tank, the Town would need to re-evaluate the ability of the system to supply these homes with adequate pressure during peak hour demand conditions and the construction of a booster station would need to be considered.

6.5.3 Piping System Deficiencies

As part of the maximum day plus fire flow and peak hour evaluations, CDM also noted water mains that were considered potentially deficient or limiting if they were predicted to have high velocities or high headlosses as described in Section 6.2.2. According to the model, the following water mains are considered potentially deficient:

- 6-inch unlined cast iron water main on Boyden Street from Main Street to Main Street
- 6-inch unlined cast iron water main on Woodland Road from Boyden Street to Highland Street
- 10-inch unlined cast iron water main on Main Street from Reservoir Street to Shrewsbury Street

6-inch Unlined Cast Iron Water Main from Holden Street

- 10-inch and 8-inch unlined cast iron water main on Shrewsbury Street from Shrewsbury Street to Brattle Street
- 6-inch unlined cast iron water main on Shrewsbury Street from Chaffin Tank Access Road to Bullard Street
- 6-inch unlined cast iron water main on Holden Street from Shrewsbury Street to Worcester town line
- 6-inch unlined cast iron water main on South Main Street from Shrewsbury Street to Newell Road
- 6-inch unlined cast iron water main on Doyle Road from Brattle Street to Worcester town line
- 6-inch unlined cast iron water main on Bailey Road from Main Street to the existing 8-inch water main

- 8-inch unlined cast iron water main on Salisbury Street/Old Salisbury Street between Main Street and the existing 12-inch water main

- 6-inch unlined cast iron water main on Reservoir Street from Main Street to the existing 12-inch water main

- 6-inch unlined cast iron water main on Chapel Street from Shrewsbury Street to Lincoln Avenue

8-inch Unlined Cast Iron Water Main from Salisbury Street

- 6-inch unlined cast iron water main on Wachusett Street from Shrewsbury Street to Lincoln Street

- 6-inch unlined cast iron water main on Lincoln Avenue from Wachusett Street to Chapel Street

- 10-inch, 8-inch and 6-inch unlined cast iron water main on Highland Street from Main Street to Union Street

The water mains listed above are considered potentially deficient because of high headlosses as a result of the low roughness coefficient c-values assigned to the small diameter unlined cast iron water mains.

6.5.4 General Piping System Deficiencies

According to the Town, the majority of water system complaints that are received can be directly attributed to system disruptions such as water main leaks and breaks that can stir up sediment in the piping system. The presence of old unlined water mains, small diameter water mains, parallel water mains and unlooped water mains encourage the buildup of sediment and corresponding customer complaints.

In addition to the potentially deficient water mains listed in Section 6.5.3, the Town should also consider removing all small diameter water mains, hydraulic bottlenecks in the system and replacing aging and problematic asbestos cement water mains when possible. For example:

- The Town should replace the small diameter water mains (e.g., less than 4-inches) on the following streets with appropriately sized water mains including hydrants and valves:

  - Anthony Drive
  - Colorado Circle
  - Parker Avenue
  - Tucker Road
  - Birch Avenue
  - Cumberland Circle
  - Paugus Road
  - Virginia Hill
  - Causeway Street
  - Fruit Street
  - Stern Lane
  - Wendover Road

- The Town should replace the 6-inch asbestos cement water main on Shrewsbury Street from Bullard Street to West Boylston town line if the Town replaces the 6-inch unlined cast iron water main on Shrewsbury Street from Chaffin Tank Access Road to Bullard Street.

- The Town should replace the 6-inch asbestos cement water main on Chapel Street from Lincoln Avenue to the existing 12-inch water main, if the Town replaces the 6-inch unlined cast iron water main on Chapel Street from Shrewsbury Street to Lincoln Avenue.

- The Town should replace the 6-inch asbestos cement water main on Mayflower Circle from Colonial Road because the water main has a history of water main breaks in recent years.

- The Town should require the installation of a new water main to connect Bailey Road to Reservoir Street as part of any new development planned for this area to better hydraulically connect the Chapin Road Tank to the center of Town.

- Similarly, the Town should require the installation of a new water main to connect Stanjoy Drive to Winter Hill Drive as part of any new development planned for this area to eliminate the dead ends.

Long term rehabilitation of the water system piping network (by cleaning and cement-lining or replacement of existing older water mains) will eventually help to address these water quality complaints. The capital plan to address these system wide deficiencies will be further discussed in Section 7.

6.6 Super High Service System Analysis

The Town of Holden currently operates three super high service systems, which are supplied from the high service system. This section discusses the ability of the Town of Holden to service these customers in the event of an emergency or to provide fire protection.

6.6.1 Chapin Road Tank Super High System

The Chapin Road Tank super high service system is supplied by the Chapin Tank Booster Station located on Sycamore Drive. The Chapin Tank Booster Station contains two 25-hp end suction style pumps each with a capacity of approximately 400 gpm and an emergency standby generator. Therefore, the Chapin Tank Booster Station is adequately designed with redundant pumps and standby power to allow the station to operate in the event of a mechanical failure or a power failure. In addition, the Chapin Road Tank super high service system is served by the Chapin Road Tank, which is adequately sized to provide fire protection and emergency volume (see Section 6.3 and 6.4). The Chapin Road Tank super high system is also adequately designed to provide peak hour flow while maintaining a minimum zone pressure of

35 psi and to supply 1,000 gpm of fire flow to all locations while maintaining a minimum zone pressure of 20 psi.

6.6.2 Fox Hill Development Super High System

The Fox Hill Development super high service system encompasses approximately 50 homes, which is supplied by the Sycamore Drive Booster Station also located on Sycamore Drive. The Sycamore Drive Booster Station currently contains two 7.5-hp end suction style pumps each with a capacity of approximately 150 gpm and an emergency standby generator. Therefore, the Sycamore Drive Booster Station is adequately designed with redundant pumps and standby power to allow the station to operate in the event of a mechanical failure or a power failure. The Sycamore Drive Booster Station is also adequately designed to provide peak hour flow while maintaining a minimum zone pressure of 35 psi. In addition, there is adequate supply and storage within the high service system to maintain water supply to the Sycamore Drive Booster Station under all conditions (see Section 6.3 and 6.4).

In the event of a fire in the Fox Hill Development super high service system, there is a check valve located at the Sycamore Drive Booster Station, which will allow water to enter the super high service system directly from the high service system. Based on the current configuration of the Sycamore Drive Booster Station, the system is able to supply only 250 gpm of fire flow to all locations while maintaining a minimum zone pressure of 20 psi within the Fox Hill Development. The available fire flow within the Fox Hill Development super high service system is limited because of the high elevation area located at Holley Circle (approximate ground elevation is 975-ft MSL). If the minimum zone pressure was allowed to drop below 20 psi, but still required a minimum hydrant pressure of 20 psi, the available fire flow within the Fox Hill Development super high service system would increase to approximately 500 gpm at all locations with the exception of Holley Circle.

One option is to interconnect the Fox Hill Development and the Chapin Road Tank super high service systems with a check valve that would allow water to enter the Fox Hill Development from the Chapin Road Tank system, which is at a higher hydraulic grade line than the high service system. This option would increase the available fire flow within the Fox Hill Development super high service system to approximately 1,000 gpm at all locations with the exception again of Holley Circle even if the minimum zone pressure was allowed to drop below 20 psi but still requiring a minimum hydrant pressure of 20 psi.

Over the long-term, CDM recommends that the Town install a permanent fire pump at the Sycamore Drive Booster Station to provide adequate fire protection to the Fox Hill Development as part of an overall facility improvement project. In the meantime, CDM recommends that the Town develop a fire protection plan with the Fire Department for the Fox Hill Development. This fire protection plan could include the recommendation that the fire department pump water from a hydrant located in the Chapin Road super high system to a hydrant located in the Fox Hill Development to maintain pressure at Holley Circle during a fire flow event. This fire protection plan may require the Town to install new hydrants within close proximity to each other in order to allow the Fire Department to pump water from the Chapin Road super high system to the Fox Hill Development.

6.6.3 Morningside Development Super High System

The Morningside Development super high service system encompasses approximately 150 homes between Greystone Drive and Avery Heights Drive. The Morningside Development super high service system is supplied by the Morgan Circle Booster Station located on Morgan Circle by the Avery Heights Storage Tank. The Morgan Circle Booster Station was also designed to replace the aging Avery Heights and Reservoir Street Booster Stations.

The Morgan Circle Booster Station contains one 3-hp jockey pump, one 20-hp lead pump, and two 40-hp lag pumps end suction style pumps and an emergency standby generator. The lead pump has a capacity of approximately 500 gpm and the lag pumps have a capacity of approximately 1,200 gpm each. The total capacity of the station is approximately 2,100 gpm. The lead pump is equipped with a variable frequency drive (VFD), which controls the lead pump speed to maintain the desired pressure within the service area. The operation of the pumping system is controlled by a local control panel, which controls the number of pumps in operation and the pump operating sequence in order to maintain the desired flow and pressure within the service zone.

For the most part, the Morgan Circle Booster Station is adequately designed with redundant pumps (i.e., two lag pumps) and standby power to allow the station to operate in the event of a mechanical failure or a power failure. Based on a review of the current station operation, only the lead pump operates to supply water to the Morningside Development. Therefore, CDM recommends that the Town replace the jockey pump, with equally sized lead pump and VFD to provide adequate redundancy.

Overall, there is adequate supply and storage within the high service system to maintain water supply to the Morgan Circle Booster Station under all conditions (see Section 6.3 and 6.4). The Morgan Circle Booster Station is adequately designed to provide peak hour flow while maintaining a minimum zone pressure of 35 psi. In the event of a fire in the Morningside Development super high service system, the lag pump within the Morgan Circle Booster Station has sufficient capacity to maintain water pressure (20 psi) and provide fire flow (1,000 gpm). The water mains within the Morningside Development super high system are also adequately sized to supply a 1,000 gpm fire flow to all locations.

6.7 Additional System Analysis

As part of the water distribution system master plan, CDM also performed additional water distribution system analyses using the computer model and conducted specific operations evaluations on select facilities.

6.7.1 Salisbury Street Interconnection Booster Station Operating Parameters Evaluation

CDM conducted hydraulic model simulations to develop SCADA system operating parameters with the newly constructed Salisbury Street Interconnection Booster Station on-line. The goal of the SCADA system operation evaluation was to develop successful SCADA system control logic with the newly built Salisbury Street Interconnection Booster Station. For the purpose of the evaluation, successful SCADA system logic control operation was defined as the ability to maximize in-town water supply, while regularly refilling all the water storage tanks. The proposed operating parameters for the Salisbury Street Interconnection Booster Station were submitted to the Town in a separate technical memorandum date January 3, 2006.

6.7.2 Chapin Road Tank Operation Evaluation

CDM conducted an evaluation of the impacts to the distribution system of allowing the Chapin Road Tank to operate on the high service system along with the Avery Heights and Jefferson Water Storage Tanks. The objective of the evaluation was to determine if water level fluctuation within the Chapin Road Tank could be improved and if the operations of the water distribution system could be simplified by allowing the Chapin Road Tank to operate on the high service system.

As stated in the Chapin Road Tank Operation Evaluation Technical Memorandum dated January 4, 2006, the Town could operate the Chapin Road Tank on the high service system with minor SCADA system operating parameter modifications and conversion of the existing Chapin Road Tank PRV into an altitude valve to force water into the other water storage tanks. As a result, the Town would improve water level fluctuation within the Chapin Road Tank to help ensure tank water quality, and simplify distribution system operations in the Chapin Road Tank area. In addition, the Town would realize a cost savings by not having to operate the Chapin Road Booster Station to refill the Chapin Road Tank.

However, by allow the Chapin Road Tank to operate on the high service system, the Town would lose approximately 1 MG of active storage. This would reduce the total active storage volume surplus within the high/super high system from 1.73 MG to 0.73 MG. The high/super high service system would still have adequate equalization storage volume and fire protection storage volume (see Section 6.3). However, the high/super high service system would not have sufficient emergency storage for all emergency conditions (see Section 6.4).

Currently, the Town is unable to adequately fluctuate the water level within the Chapin Road Tank due to operational issues of the Chapin Road PRV. Water from the

Chapin Road Tank is allowed to leave the small super high system and flow into the high service system via the PRV located in a below ground vault at the intersection of Fox Hill Road and Sycamore Drive. The Chapin Road PRV is equipped with an electronically controlled pressure regulating pilot, which can be controlled via the SCADA system. Unfortunately, as a result of the damp environment associated with the below ground vault, the Chapin Road PRV has had on-going maintenance issues.

One solution would be to upgrade the existing PRV located within the Chapin Road Booster Station to an electrically controlled valve, similar to the Brattle Street Interconnection Valve, and abandon the Chapin Road PRV located within the below ground vault. The Chapin Road Booster Station is climate-controlled and above ground, which would allow for the installation of more sophisticated valve controls and allow for easier valve maintenance by the operators. By upgrading the existing PRV located within the Chapin Road Booster Station, the Town would be able to maintain the current level of available water storage volume while providing the Town with improved control of the water level within the Chapin Road Tank. In addition, by abandoning the Chapin Road PRV, the number of facilities maintained by the Town would be reduced.

6.7.3 Rutland Emergency Water Supply Interconnection Evaluation

CDM conducted an evaluation related to Rutland's request for an emergency water supply interconnection with Holden. The purpose of this evaluation was to determine if Holden is able to provide Rutland with 0.5 MGD during an emergency, with regard to Holden's supply capacity and system hydraulic capacity.

As stated in the Rutland Emergency Water Supply Interconnection Evaluation Technical Memorandum dated January 4, 2006, Holden's system capacity is sufficient to meet the projected maximum day demand plus Rutland's proposed emergency supply requirement to 2020. However, according to water demand projections, Holden does not have sufficient capacity to supply Rutland after 2020 without increasing the supply capacity of the Salisbury Street Interconnection Booster Station. [Note: that the installed capacity of the booster station is 2.1 mgd, with an expansion capacity of 3.0 mgd. Any increase in capacity; however, requires filing an Interbasin Transfer Act application.]

Hydraulically, as a result of the proposed Rutland emergency supply interconnection location in proximity to the Jefferson Storage Tank and the distance from Holden's water supply sources, it would be difficult for Holden to maintain the water level within the Jefferson Storage Tank during Rutland emergency supply conditions. However, the impact of the proposed Rutland emergency supply interconnection could be mitigated by: (1) limiting the number of consecutive days of operation, (2) reducing the system demand by instituting water conservation measures in Holden an Rutland during this emergency situation, (3) increasing the allowable outlet pressure at the Brattle Street Interconnection to increase the water supply via the

Brattle Street Interconnection and force more water toward the Jefferson Water Storage Tank, or (4) proposing a different Rutland emergency interconnection location to reduce the impacts to the Jefferson Water Storage Tank. These options are discussed in further detailed in the Rutland Emergency Water Supply Interconnection Evaluation Technical Memorandum dated January 4, 2006.

6.7.4 Water Storage Tank Inspection Evaluation

CDM reviewed the water storage tank inspections performed by Underwater Solutions, Inc. during the week of January 10 through 14, 2005. Underwater Solutions inspected the interior and exterior coatings and the tank appurtenances (hatches, manways, vents, overflow pipes, etc.). During the inspection, sediment accumulated on the floor of each tank was vacuumed and removed.

As stated in the Water Storage Tank Inspection Evaluation Technical Memorandum dated April 25, 2005, CDM recommends that the Town evaluate leakage and perform structural analysis at Highland Street Storage Tank. CDM also recommends that the Town inspect and address the coating failure of the Chapin Road Tank roof interior and inspect the Avery Heights coating system. The April 25, 2005, Technical Memorandum also includes estimated planning level costs for these rehabilitation recommendations.

6.8 Summary of Existing System Deficiencies

Based on the analyses conducted on the existing storage, pumping and piping facilities, the following conclusions were made regarding the adequacy of the existing system to meet projected water system demands for 2030.

- There is adequate active storage volume in the system to meet projected future demand conditions. To improve water level operation within the Chapin Road Tank, CDM recommends an upgrade to the existing PRV located within the Chapin Road Booster Station to an electrically controlled valve, similar to the Brattle Street Interconnection Valve, and abandon the Chapin Road PRV located within the below ground vault. CDM also recommends that the Town perform a structural analysis of the Highland Street Storage Tank and inspect and rehabilitate steel tank coating systems of the Chapin Road Tank and Avery Heights Tank.

- There are adequate pumping facilities to supply all zones to meet projected future demands. The pumping facilities also have sufficient pumping redundancy and the system has adequate emergency storage volume to supply projected max day demand under various emergency conditions in all service zones with the exception of the Morningside Development super high system and Fox Hill Development super high system. For the Morningside Development super high system, CDM recommends that the Town install a second lead pump and VFD to provide adequate redundancy at the Morgan Circle Booster Station. For the Fox Hill Development super high system, CDM recommends that the Town install a permanent fire pump at the Sycamore Drive Booster Station to provide adequate fire protection. Until a permanent fire pump is installed at the Sycamore Drive Booster Station, CDM recommends that the Town develop fire protection plan with the Fire Department and install two hydrants located near the Chapin Road Tank access road to allow the Fire Department to pump water from the Chapin Road Tank super high system into the Fox Hill Development super high system. CDM also recommends that the Town purchase a portable standby generator for the Brattle Street Valve Vault in order to operate the facility fully during an emergency power failure.

- In general, Holden's water distribution system is considered hydraulically well-connected. The water distribution system can meet projected future demands while maintaining a residual of 35 psi or greater throughout the system, with the exception of the very limited areas immediately surrounding the water storage tanks. As predicted by the model, the water distribution system is also able to provide the required fire flows under projected future demands at all ISO test locations, with the exception of Boyden Street at Woodland Road.

- Replacing the 6-inch unlined cast iron water main on Boyden Street and the 6-inch unlined cast iron water main on Woodland Road with new 8-inch cement lined ductile iron water mains would address the one deficient ISO fire flow area.

- Overall, by replacing or rehabilitating the other hydraulically deficient water mains listed in Section 6.5, the Town will eventually help address the majority of water quality complaints associated with system disruptions and dirty water. In addition, the Town should remove all small diameter water mains, hydraulic bottlenecks in the system and replace aging and problematic asbestos cement water mains whenever possible.

Recommendations for capital improvements to the distribution system are further discussed in Section 7. These improvements are aimed at correcting the water distribution system inadequacies discussed above.

Section 7
Recommended Improvement Program

7.1 General

This section presents the water distribution system improvements that are required to correct system deficiencies identified in Section 6. The overall objective of these improvements is to provide adequate system flow capacity, meet pressure criteria, and improve reliability and water quality.

The recommended improvement program is arranged in four categories:

- Geographic Information System (GIS) Implementation
- Annual Maintenance Program Recommendations
- Storage and Pumping Station Capital Improvements
- Piping System Capital Improvements

Implementation of GIS will provide the Town with updated water system mapping and asset inventory, which will assist the water department in operation and maintenance efforts and capital planning decisions. The Annual Maintenance Program Recommendations address such things as storage facility inspection programs and hydrant and valve maintenance programs. These programs should be initiated as soon as possible and run over the long-term since proper operation and maintenance of these facilities can result in significant improvements in system hydraulics and water quality. Storage and Pumping Station Capital Improvements address storage and pumping station deficiencies identified in Section 6. These capital improvements will improve available storage and distribution system reliability and are therefore a high priority. Piping System Capital Improvements address piping system deficiencies identified in the hydraulic analysis. These capital improvements will improve the overall piping network reliability and water quality and can be implemented over the long-term (see appended Water Main Rehabilitation Map)

Table 7-1 provides an estimated annual allowance for the Annual Maintenance Program. Table 7-2 provides an estimated construction project cost for Storage and Pump Station Capital Improvements. Table 7-4 provides an estimated construction project cost for Piping System Capital Improvements. The estimated annual allowances and estimated construction project cost in the tables are based on current construction and engineering costs as of April 2006 and are referenced to an Engineering News Record (ENR) Construction Cost Index of 7695. The estimated construction project cost for the capital improvements also includes an allowance of 45 percent for engineering and contingencies.

7.2 Geographic Information System (GIS)

The Town is currently implementing a town-wide geographic information system (GIS) to help maintain and manage all records and information, including that of the water distribution system. Implementation of town-wide GIS will provide the following benefits to the Water Department:

- ***Water System Maps**:* The Holden Water Department currently has water system mapping data stored in many different locations and in many different formats. In addition, some of the information is old and in need of updating. Implementation of GIS will provide the Water Department with the mechanism to digitally store all water system information in a centralized location. GIS implementation will also provide the Water Department with the opportunity to update all of its records, which will allow development of more accurate maps.

- ***Water System Asset Inventory***: GIS will allow the Water Department to develop a complete inventory of the water system's assets. This will include identifying the physical location of water system features (i.e., gate valves and hydrants), as well as compiling detailed information (e.g., size, age, etc.) of each feature. The inventory will support the implementation of advanced management operations, such as maintenance programs that keep detailed maintenance history on each asset. This will allow the Town to make informative decisions on where improvements need to occur.

- ***Rapid Data Access:*** GIS will allow employees to rapidly access water system mapping information. Detailed mapping information can potentially be made available in the field for the Water Department so that determinations can be made when an emergency situation occurs.

- ***Capital Planning and System Analysis:*** GIS will provide the Water Department with a tool to support capital planning and system analysis. This includes the ability to support capacity analysis and maintenance programs, such as hydrant flushing, which can result in substantial time and cost savings

- ***Engineering Design Support**:* GIS also can support the water system design process, by potentially minimizing survey time needed.

Overall, the implementation of GIS for the Town will provide the Water Department with more accurate water system maps and will help manage the water system maintenance program. The GIS Needs Assessment (CDM, 2004) provided a planning level cost for development of GIS maps, assuming water mains imported from the model and valve and hydrant locations from available flushing maps. If the Town wishes to expand the GIS mapping effort to include an electronic inventory of facility information based upon tie-cards and other records, then the cost of GIS development for the water system would increase to a range of $30,000 to $60,000. If the Town prefers to field survey all hydrants and valves using GPS (global positioning satellite system), there would be an additional cost of approximately $15,000 to $20,000.

7.3 Annual Maintenance Program Recommendation

Comprehensive water system inspection and maintenance programs are critical for any water distribution system. These programs are extremely effective in extending the life of existing water system facilities and optimizing the Town's investment in its infrastructure. In addition to the asset management benefits, proper maintenance of the distribution and supply facilities reduces long-term maintenance costs and reduces the potential of a catastrophic failure of segments of the system during critical operating periods. Maintaining the existing water system also optimizes available hydraulic capacity, thus minimizing the need to increase capacity by investing in additional piping. Finally, proper maintenance can also improve water quality by reducing the number of inadvertently closed valves in the system and ensuring the proper operation of the storage and supply facilities.

7.3.1 Valve Maintenance Program

The Town should initiate a comprehensive valve exercising program. It should be the goal of this program to operate every valve on a regular basis. The preferred approach is to exercise every valve in the system annually. If staffing is of issue, the Town could exercise valves annually on all water mains 10-inches and greater, with the smaller valves exercised every three years. This valve maintenance program will ensure that no valve is inadvertently left closed following construction, water main repair or for other maintenance activity. Some guidelines to consider when developing the valve maintenance program are:

- Any valves that do not completely close or open should be replaced.
- Valves that leak around the stems should be repacked.
- Valves should be exercised in both directions (fully open and fully closed) and the number of turns and direction of the operation recorded.
- Valves operating in a direction opposite to that which is standard for the system need to be identified and replaced.
- The Town should consider conducting the annual valve exercising program to coincide with the hydrant maintenance program.

Table 7-1 provides an estimated annual allowance to purchase 20 valves per year which covers approximately 2 percent of the Town. The estimated annual allowance does not include labor costs, as it is assumed that the replacement valves will be installed by Town forces. The estimated annual allowance should be adjusted upward each year for inflation.

The valve maintenance program can be performed along with the hydrant maintenance program and the unidirectional flushing program, as discussed below. The consolidation of these maintenance programs will minimize the time required and enable the town to proceed systematically through the system collecting comprehensive distribution system data. In addition, the geographic information system (GIS) (once developed for the Town) can be used to plan and document the results from the valve maintenance program. When maintained properly, this GIS system can be an invaluable asset to the operations of the Holden Water Department.

7.3.2 Hydrant Maintenance Program

The Town should initiate a rigorous hydrant maintenance program. The goal of this program should be to operate every hydrant at least once a year. Some elements of this program may be conducted in cooperation with the Fire Department. The following procedures are recommended for hydrant inspection and maintenance:

- Inspect for leakage and make corrections where necessary.
- Open hydrant fully, checking for ease of operation.
- Flush hydrant barrel to waste (take care to direct flow).
- Remove all nozzle caps and inspect for thread damage from impact or cross threading. Wire-brush the nozzle and cap threads. Clean and lubricate outlet nozzle threads, preferable with dry graphite-based lubricant, and check ease of operation. Check that the nozzle cap gaskets are in good condition.
- Replace caps, tighten with spanner wrench, then back off on the threads slightly so that the caps will not be excessively tight, but will leave sufficient frictional resistance to prevent removal by hand.
- Check for any exterior obstruction that could interfere with hydrant operation during an operation.
- Check dry-barrel hydrants for proper drainage.
- Clean exterior of hydrant and repaint in accordance with Town standards, if necessary.
- Be sure that the valve on the hydrant branch line is in the fully open position.
- If hydrant is inoperable, tag it with a clearly visible marking to prevent loss of time by firefighting crews if an emergency should arise before the hydrant is repaired. Immediately report the condition of the fire hydrant to the Fire Department.
- Prepare a report of inspection and maintenance operation and any repair work.

Table 7-1 provides an estimated annual allowance to purchase 20 hydrants per year to cover approximately 2 percent of the Town. The estimated annual allowance does not include labor costs, as it is assumed that the replacement hydrants will be installed by Town forces. The estimated annual allowance should be adjusted upward each year for inflation.

The hydrant maintenance program can be performed along with the valve maintenance program and the unidirectional flushing program. As discussed above, the consolidation of these maintenance programs will minimize the time required and enable the town to proceed systematically through the system collecting comprehensive distribution system data. In addition, the GIS system (once developed for the Town) can be used to plan and document the results from the hydrant maintenance program.

7.3.3 Unidirectional Flushing Program

The Holden distribution system displays signs of sediment and tuberculation build-up within the distribution piping. This is evident from customer complaints, in addition to the water quality observed at hydrants when operated.

As a general rule for Holden, distribution system flushing should be implemented to clear up areas that are experiencing water quality issues. Unidirectional flushing is recommended to ensure that the flushing procedures are effective and that each single pipe is isolated during the flush. Unidirectional flushing involves isolating each pipe by a series of valve maneuvers such that the flow proceeds from a clean water source down the isolated pipe to the flushing hydrant. Flushing should be continued for a sufficient amount time to clean the system of poor quality water and sediment.

CDM prepared a unidirectional flushing program for Holden dated March 22, 2006, that outlines the detailed procedures required. According to the flushing program submitted to the Town, CDM recommends implementing the flushing program over a 2-year period in which two of the eight flushing areas are cleaned in both the spring and fall. As stated above, the valve and hydrant maintenance programs and the unidirectional flushing program can be completed concurrently. The Town could employ a field crew to check all the valves and hydrants within a flushing area prior to performing the unidirectional flushing program. This would ensure that all valves and hydrants are accessible and operable for the flushing program, which would ultimately save time during the unidirectional flushing program.

Table 7-1 provides an estimated annual allowance to purchase additional water from Worcester to flush 4 areas per year based on the flushing program performed in November 2004. The estimated annual allowance does not include labor costs, as it is assumed that the flushing program will be performed by Town forces. The estimated annual allowance should be adjusted upward each year for inflation.

7.3.4 Storage Tank Inspection Program

Interior and exterior inspection of the storage tanks should be routinely conducted. Interior inspection can be accomplished by diver or remotely operated vehicle equipment with a video camera. Internal inspection can reveal information on the level of sediments and the condition of walls and floors. Concrete tanks should be inspected externally for cracks and signs of leakage. The condition of steel tanks must be assessed regularly regarding coating systems, such that repairs can be accomplished in a timely manner. It is recommended by AWWA that internal and external inspections be performed every five years.

Table 7-1 provides an estimated annual cost to inspect each water storage tank every five years. The estimated annual cost was based on the water storage tank inspections performed in 2004 by Underwater Storage. The estimated annual cost to inspect the water storage tanks was increased to provide an allowance for a coating system engineer and structural engineer to review the live video footage during the internal inspection. The estimated annual cost should be adjusted upward each year for inflation.

7.3.5 Wellfield Redevelopment Program

Redevelopment and rehabilitation of the in-town wellfields is recommended in order to keep wellfield yields near their original ratings. This will also save money for the town as less water will need to be purchased from the City of Worcester. The Mason Road Wellfield was last redeveloped in 2002, the Spring Street Replacement Well was installed in 2003, the Mill Street Wellfield was redeveloped in 2004, and the Quinapoxet Well No. 2 was redeveloped in 2005.

To assess the need for well/wellfield redevelopment the Town should continue collecting water level readings to assess drawdown relative to pumping rate. In addition, the Town should annually assess specific capacity at each production well (i.e., Spring Street and Quinapoxet Wells). A 25 percent reduction in specific capacity typically suggests the need for well redevelopment. At the tubular wellfields (i.e., Mill and Mason), monitoring of vacuum pressure over time may indicate a reduction in capacity, such that wellfield rehabilitation should be considered.

For budgetary purposes, CDM recommends that the Town budget redevelopment of one well/wellfield per year, recognizing that the schedule of implementation for each well will vary by such factors as iron/manganese concentration. Table 7-1 provides an estimated annual cost to inspect and redevelop a well/wellfield each year. The estimated annual cost was based on recent wellfield redevelopment performed by D.L. Maher. The estimated annual cost also includes an allowance for miscellaneous pump/motor and piping repairs to each well/wellfield. The estimated annual cost should be adjusted upward each year for inflation.

7.3.6 Water Conservation Program

CDM recommends that the Town continue its water conservation program. Consideration may be given to developing additional public education material relative to water conservation. The Town could also purchase and make available to the public different water conservation devices such as low flow showerheads, faucet aerators, toilet tank dams, toilet leak detection dye tablets, plastic rain gauges, and soil moisture meters, etc. An annual allowance for continuation of water conservation efforts based on the Town's preferences is identified in Table 7-1. The estimated annual allowance should be adjusted upward each year for inflation.

7.3.7 Unaccounted-for Water Reduction Program

The Town has implemented an aggressive water conservation and unaccounted-for water reduction program. This was necessary during periods of supply shortfalls as new water system facilities were brought on-line. Whenever possible the Town must continue these efforts in order to maintain compliance with Water Management Act

(WMA) permit requirements. In addition, the intermunicipal agreement with Worcester requires compliance with a 15 percent unaccounted-for water percentage.

The following summarizes key components of the Town's unaccounted-for water reduction program.

Water Audit Program

The first step in reducing unaccounted-for water is for the Town to perform a detailed water audit to more accurately estimate water loss. CDM recommends that the Town perform a detailed water audit every year. CDM assumed that the water audit would be performed by town staff.

Meter Replacement Program

An unfortunate characteristic of water meters is that they tend to under-record with age, sometimes losing up to 1 percent of accuracy per year, which can represent a major portion of unaccounted-for water. Accordingly, replacing customer water meters every 10 to 12 years is recommended to reduce this component of unaccounted-for water and in turn capture lost revenue.

In 2005, the Town of Holden completed a residential water meter replacement program. This program included the installation of approximately 6,000 water meters and the retrofit of approximately 100 water meters. The new water meters were Badger Recordall® Disc Series water meters with integral electronic meter reading capability via radio transmitter. The new meters send a radio signal which is picked up by a receiver located in the vehicle of the town water meter reader. Instead of the meter reader having to walk to each property to read each meter, the meter reader can drive down the street to collect all the readings. The meter reader then takes this information to the billing office where it is downloaded to the billing system. This approach has greatly increased the accuracy and efficiency of reading water meters. As a result, the Town has moved to monthly water and sewer billing as opposed to quarterly. This allows the customer to monitor usage more closely, thereby allowing a leak to be identified sooner.

Table 7-1 provides an estimated annual allowance to purchase 300 meters per year to replace approximately 5 percent of the Town's meters beginning in 5-years. The estimated cost of the new water meters were based on the recent water meter replacement program. The estimated annual allowance does not include installation cost as it is assumed that the replacement meters will be installed by the Town's water department. The estimated annual allowance should be adjusted upward each year for inflation.

Master Meter Calibration Program

If not periodically calibrated, master meters at the well pump station and interconnections can produce significant registration errors which contribute to unaccounted-for water. To ensure WMA permit compliance, the water department must continue its practice of testing and recalibrating each master meter annually.

Table 7-1 provides an estimated annual cost to test and calibrate each master meter every year. The estimated cost of testing and calibrating the master meters were based on the recent master meter calibration program performed by the Town in 2005. The estimated annual allowance should be adjusted upward each year for inflation.

Leak Detection Program

Water main leaks also account for a major portion of unaccounted-for water. A comprehensive leak detection survey was performed by the Town in 2005. The Town should continue to conduct leak detection surveys every two years to ensure WMA permit compliance. In addition, the Town should repair any leak reported within a timely fashion to reduce the amount of unaccounted-for water.

Table 7-1 provides an estimated annual cost to perform a town-wide leak detection survey every two years. The estimated cost of performing a town-wide leak detection survey was based on the recent leak detection survey performed in 2005. The estimated annual cost should be adjusted upward each year for inflation.

Table 7-1
Summary of Annual Maintenance Programs

Annual Maintenance Program	*Estimated Annual Cost* [1]
Valve Maintenance Program	$30,000
Hydrant Maintenance Program	$20,000
Unidirectional Flushing Program	$15,000
Storage Tank Inspection Program	$5,000
Wellfield Redevelopment Program	$25,000
Water Conservation Program	$15,000
Unaccounted-for Water Reduction Program	
Water Audit Program [2]	-
Meter Replacement Program [3]	$50,000
Master Meter Calibration Program	$5,000
Leak Detection Program	$10,000
Total	**$175,000**

Notes: 1. Estimated annual cost only covers the cost of materials, water purchase from Worcester and/or subcontractors including contingency. Estimated annual cost does not include cost of town forces. All costs are in year 2006 dollars (ENR April 2006 = 7695).
2. No cost shown as work assumed to be performed by Town.
3. The anticipated start date of the Meter Replacement Program is 2010.

7.4 Storage and Pump Station Capital Improvements

Storage and Pump Station Capital Improvements include all the system improvements required to address storage and pumping station deficiencies identified in Section 6. These capital improvements will improve available storage and distribution system reliability and are therefore a high priority.

7.4.1 Water Storage Tank Improvements

In January 2005, the Town hired Underwater Solutions, Inc. to inspect and clean all the water storage tanks. Underwater Solutions inspected the interior and exterior coatings and the tank appurtenances (hatches, manways, vents, overflow pipes, etc.). During the inspection, sediment accumulated on the floor of each tank was vacuumed and removed.

Underwater Solutions recommended the recoating of the Avery Heights Standpipe and the Chapin Road Reservoir within two (2) years and additional inspection of the concrete walls at the Highland Street Reservoir by Natgun Corporation. CDM also recommends that the Town evaluate leakage and perform structural analysis at the Highland Street Reservoir, plus address the coating failure of the Chapin roof interior.

The planning level cost range with Table 7-2 to rehabilitate the Avery Heights and Chapin Road Tanks are based on the planning level costs provided in the Water Storage Tank Facilities Evaluation technical memorandum (CDM, April 25, 2005) and adjusted to April 2006 dollars. No planning level cost can be provided at this time to structurally repair the Highland Street Reservoir due to the many variables associated with this type of repair. Following the leakage test and structural inspection, a planning level cost estimate for the repairs can be developed. In Table 7-2, only the planning level cost estimate to structurally inspect the Highland Street Reservoir is provided.

7.4.2 Water Storage Tank Operation Improvements

Currently, the Town is unable to adequately fluctuate the water level within the Chapin Road Tank because of operational issues with the Chapin Road PRV. As stated in Section 6, CDM recommends that the Town upgrade the existing PRV located within the Chapin Road Booster Station to an electrically controlled valve, similar to the Brattle Street Interconnection Valve, and abandon the Chapin Road PRV located within the below ground vault. By upgrading the existing PRV located within the Chapin Road Booster Station, the Town would be able to maintain the current level of available water storage volume while providing the Town with improved control of the water level within the Chapin Road Tank.

Table 7-2 provides the planning level cost estimate to upgrade the existing PRV located within the Chapin Road Booster Station to an electrically controlled valve.

7.4.3 Pumping Station Improvements

As stated in Section 6, there appears to be adequate pumping redundancy to supply projected maximum day demand under various emergency conditions in all service zones, with the exception of the Morningside Development super high system and Fox Hill Development super high system. To address these deficiencies, CDM recommends that the Town: (1) install a second lead pump and VFD to provide adequate redundancy within the Morgan Circle Booster Station for the Morningside Development super high system; (2) develop a fire protection plan with the Fire

Department and install two hydrants located near the Chapin Road Tank access road to allow the Fire Department to pump water from the Chapin Road Tank super high system into the Fox Hill Development super high system (short-term solution) during an emergency; and, (3) in the future, install a permanent fire pump at the Sycamore Drive Booster Station to provide adequate fire protection for the Fox Hill Development super high system (long-term solution). Table 7-2 provides the planning level cost estimate for each of these upgrades.

7.4.4 Supply Facility Improvement

As stated in Section 6, there appears to be adequate facilities to supply projected maximum day demand under various emergency conditions in all service zones. However, CDM recommends that the Town purchase a portable standby generator for the Brattle Street Valve Vault in order to operate the supply facility fully during an emergency power failure.

Table 7-2 provides the planning level cost estimate to install a manual transfer switch and purchase a portable standby generator for the Brattle Street Valve Vault.

Table 7-2
Summary of Storage and Pump Station Capital Improvement Program

Capital Improvement Program	*Estimated Planning Level Cost* [1]
Water Storage Tank Improvements:	
Avery Heights Standpipe Painting [2]	$375,000 - $525,000
Chapin Tank Reservoir Painting [2]	$650,000 - $850,000
Highland Street Structural Inspection	$5,000
Highland Street Structural Repairs [3]	Not Available
Water Storage Tank Operation Improvement:	
Chapin Tank Booster Station/PRV Upgrade	$75,000
Pumping Station Improvements:	
Morgan Circle Booster Station – New Lead Pump [4]	$50,000
Sycamore Drive Booster Station – Develop Fire Protection Plan and Install New Hydrants (Short-Term Solution)	$5,000
Sycamore Drive Booster Station – New Pump Skid with Fire Pump (Long-Term Solution)	$225,000
Supply Facility Improvement:	
Brattle Street Interconnection – Portable Standby Generator [5]	$10,000

Note:
1. The estimated planning level costs for water storage tank operation, pump station and supply facility improvements include construction, engineering and contingency. All costs are in year 2006 dollars (ENR April 2006 = 7695).
2. The tank painting costs will depend on the type of exterior surface preparation and exterior containment required. Cost does not include additional water purchase when tank(s) are off-line, if required.
3. No planning level cost can be provided until structural inspection complete.
4. The estimated planning level cost for the Morgan Circle Booster Station assumes the Town will procure the services of a factory authorized service provider for SyncroFlo (formally Liquid-trol) pump systems without the need for formal bid documents.
5. The estimated planning level cost for the Brattle Street Interconnection portable standby generator assumes the Town will purchase the portable standby generator and transfer switch directly for installation by the Town's electrician.

7.5 Piping System Capital Improvements

The Piping System Capital Improvements include recommendations for general piping system rehabilitation, including replacement or cleaning and cement lining unlined cast iron water mains, to address the piping system deficiencies identified in the hydraulic analysis. These capital improvements will improve the overall piping network reliability and water quality and can be implemented over the long-term.

Table 7-3 provides the unit costs used in developing planning level cost estimates for the Piping System Capital Improvements, which are presented in Table 7-4.

Table 7-3
Unit Costs for Piping System Capital Improvement Program

Water Main Diameter (inch)	*New Water Main Installation ($ per linear ft)*	*Cleaning and Cement Lining ($ per linear ft)*
8	$250	$150
10	NA	$170
12	$300	$175
16	$350	$200

Note: 1. Estimated unit costs include construction, engineering and contingency. All costs are in year 2006 dollars (ENR April 2006 = 7695). No allowance for legal fees, land taking or easements.

7.5.1 General Pipe Rehabilitation

As discussed previously, a significant portion of Holden's distribution system consists of unlined cast iron pipe. Many of these areas are over 50 years old and have experienced a reduction in carrying capacity due to tuberculation. In general, the carrying capacity of unlined mains will continue to be reduced as metallic salts continue to deposit on the interior walls of the pipe.

The structural integrity of very old water mains is also questionable. Exterior corrosion can weaken the strength of the pipe wall, increasing the likelihood of a break, especially in areas of the system where pressures are high. Leakage through joints and service connections is also more prevalent in older pipelines due to settlement over the years, especially in heavily traveled roadways.

Table 7-4
Summary of Piping System Capital Improvement Program

Location [1]	*From*	*To*	*Existing Pipe Diameter (in)*	*Approx. Length (ft)*	*Replacement Pipe Diameter (in)*	*Cleaning & Cement Lining*	*Estimated Planning Level Cost* [2]
Mayflower Cir.	Colonial Dr.	Colonial Dr.	6	1,000	8		$250,000
Boyden St.	Main St.	Main St.	6	1,000	8		$250,000
Woodland Rd.	Boyden St.	Highland St.	6	2,000	8		$500,000
Shrewsbury St.	Main St.	Brattle St.	10, 8	2,500/3,000		X	$850,000
Shrewsbury St.	Brattle St.	West Boylston Town Line	6	5,000	8		$1,250,000
Holden St.	Shrewsbury St.	Worcester Town Line	6	6,000	8		$1,500,000
South Main St.	Shrewsbury St.	Newell Rd.	6	6,400	8		$1,600,000
Main St.	Reservoir St.	Shrewsbury St.	10	8,500		X	$1,450,000
Bailey Rd.	Main St.	Existing 8”	6	3,000	8		$750,000
Salisbury St.	Main St.	Existing 12”	8	3,000	12		$900,000
Reservoir St.	Main St.	Existing 12”	6	1,500	12		$450,000
Doyle Rd.	Brattle St.	Worcester Town Line	6	3,000	8		$750,000
Chapel St.	Shrewsbury St.	Existing 12”	6	3,000	12		$900,000
Wachusett St.	Shrewsbury St.	End	6	1,500	8		$375,000
Lincoln Ave.	Chapel St.	End	6	1,500	8		$375,000
Highland St.	Main St.	Union St.	10, 8, 6	700/300/3,000		X	$600,000
						Total	**$12,750,000**

Note: 1. Presented in order of high to low priority

2. Estimated planning level costs include construction, engineering and contingency. All costs are in year 2006 dollars (ENR April 2006 = 7695). No allowance for legal fees, land taking or easements.

Over the long term, Holden should eventually replace or clean and cement-line all remaining unlined cast iron water mains in the distribution system with new, cement lined ductile iron pipe. There are a few items that should be considered when deciding whether to clean and line or replace a main. Replacement is generally favorable when: (1) pipe is 6-inches in diameter or less; (2) the available fire flow from the main is insufficient for full fire protection; and/or, (3) the pipe has a history of leaks and breaks. The minimum size recommended for new or replacement water mains is 8-inches. As a general rule, CDM recommends a coupon be taken from each pipe that is a candidate for cleaning and cement-lining or replacement. This practice will help verify Town records and to ensure the most beneficial use of funding.

7.5.2 Implementation of Pipe Rehabilitation Program

The total length of water main in the Piping System Capital Improvements program is approximately 10.5 miles or 10-percent of the Town's water system. These types of comprehensive pipe rehabilitation programs can only be addressed over a period of time, which may involve several decades.

There are two basic strategies for implementing such programs. The first is to set aside a given amount of funds for the programs on an annual basis. The Town could elect to perform some rehabilitation work each year or, alternatively, to collect two or more years of revenue to perform a larger rehabilitation project every few years, thereby realizing some economy of scale. Standard specifications, details, and bid documents can be prepared for use by the DPW on a repeated basis over the years. This would help minimize the engineering efforts associated with these programs.

A second basic strategy is to focus from year-to-year on streets that have other utility work being performed. Each year in Holden, there are certain streets which are scheduled to have sewer, drainage, gas, paving, or other infrastructure improvements performed. Whenever such a street also contains a water main identified in this report section, the rehabilitation of that pipe can be performed at the same time as other improvements, to reduce the overall cost. In this strategy, the priority of the piping system improvements would be set by the Town.

It is recommended that Holden consider a combination of these two strategies. An annual appropriation of funds is recommended to implement the Piping System Capital Improvements, with construction occurring either as an annual program or every 2-3 years until complete. The projects which are included in each construction package would, as priority, include streets in which work is already being scheduled for other reasons. This decision would have to be made at the time each construction package was being designed, based on the DPW's priorities at that time.

Based on the magnitude of work needed, and assuming a 30-year time frame for completion, an annual appropriation of $425,000 is suggested, adjusted upward each year for inflation. Even if this level of funding cannot be achieved, it will be to the Town's advantage to make whatever annual appropriation is possible to begin to address the most urgent rehabilitation projects.

7.6 Prioritized Capital Improvement List

Based on the improvement projects listed above, the following is a recommended prioritized list of capital improvement projects for implementation over a twenty year planning period.

Table 7-5
Prioritized Capital Improvement List

Capital Improvement Project	***Estimated Planning Level Cost*** [1]
Highest Priority Improvements (within 5 years)	
Chapin Tank Reservoir Painting [2]	$650,000 - $850,000
Highland Street Structural Inspection	$5,000
Morgan Circle Booster Station – New Lead Pump [3]	$50,000
Sycamore Drive Booster Station – Develop Fire Protection Plan and Install New Hydrants (Short-Term Solution)	$5,000
Chapin Tank Booster Station/PRV Upgrade	$75,000
Brattle Street Interconnection – Portable Standby Generator [4]	$10,000
Mayflower Circle Water Main Replacement	$250,000
High Priority Improvements (within 10 years)	
Avery Heights Standpipe Painting [2]	$375,000 - $525,000
Boyden Street Water Main Replacement	$250,000
Woodland Road Water Main Replacement	$500,000
Shrewsbury Street Water Main Cleaning and Lining	$850,000
Shrewsbury Street Water Main Replacement	$1,250,000
Holden Street Water Main Replacement	$1,500,000
South Main Street Water Main Replacement	$1,600,000
Priority Improvements (within 20 years)	
Main Street Water Main Cleaning and Lining	$1,450,000
Bailey Road Water Main Replacement	$750,000
Salisbury Street Water Main Replacement	$900,000
Reservoir Water Main Replacement	$450,000
Doyle Road Water Main Replacement	$750,000
Chapel Street Water Main Replacement	$900,000
Wachusett Street Water Main Replacement	$375,000
Lincoln Ave Water Main Replacement	$375,000
Highland Street Water Main Cleaning and Lining	$600,000
Improvements with No Timeframe	
Highland Street Structural Repairs [5]	Not Available
Sycamore Drive Booster Station – New Pump Skid with Fire Pump (Long-Term Solution)	$225,000

Note:
1. The estimated planning level costs for water storage tank operation, pump station, supply facility and piping system improvements include construction, engineering and contingency. All costs are in year 2006 dollars (ENR April 2006 = 7695). No allowance for legal fees, land taking or easements.
2. The tank painting costs will depend on the type of exterior surface preparation and exterior containment required. Cost does not include additional water purchase when tank(s) are off-line, if required.
3. The estimated planning level cost for the Morgan Circle Booster Station assumes the Town will procure the services of a factory authorized service provider for SyncroFlo (formally Liquid-trol) pump systems without the need for formal bid documents.
4. The estimated planning level cost for the Brattle Street Interconnection portable standby generator assumes the Town will purchase the portable standby generator and transfer switch directly for installation by the Town's electrician.
5. No planning level cost can be provided until structural inspection complete.

Appendix A
Water Distribution System Map

NOTE: LOCATIONS OF ROADS, SURFACE WATER AND WETLANDS ARE APPROXIMATE AND FOR GENERAL INFORMATION USE ONLY.

CAMP DRESSER & McKEE INC.

environmental engineers, scientists, planners, & management consultants **CDM**

LEGEND

- 4-INCH AND UNDER WATER MAINS
- 6-INCH WATER MAINS
- 8-INCH WATER MAINS
- 10-INCH WATER MAINS
- 12-INCH WATER MAINS
- 14-INCH WATER MAINS
- 16-INCH WATER MAINS
- 18-INCH WATER MAINS
- 20-INCH WATER MAINS
- 24-INCH WATER MAINS
- WATER STORAGE TANK
- PUMP STATION
- VALVE
- BOUNDARY OF HIGH/LOW SERVICE AREA
- RAILROAD TRACKS
- A — QUABBIN AQUEDUCT
- POND, LAKE OR RESERVOIR
- MARSH, SWAMP OR WETLAND
- BROOK, STREAM OR RIVER

SCALE 1" = 1000'

500 0 1000 2000

REVISED TO: APRIL 2006

TOWN OF HOLDEN, MASSACHUSETTS

WATER DISTRIBUTION SYSTEM MAP

PROJECT NO. 0375-24646
FILE NAMEMASTERPLANMAP.DWG

MAP NO.
1

Appendix B

Water Main Rehabilitation Map

NOTE: LOCATIONS OF ROADS, SURFACE WATER AND WETLANDS ARE APPROXIMATE AND FOR GENERAL INFORMATION USE ONLY.

CAMP DRESSER & McKEE INC.

environmental engineers, scientists, planners, & management consultants CDM

LEGEND

4-INCH AND UNDER WATER MAINS	14-INCH WATER MAINS	WATER STORAGE TANK	A QUABBIN AQUEDUCT
6-INCH WATER MAINS	16-INCH WATER MAINS	PUMP STATION	POND, LAKE OR RESERVOIR
8-INCH WATER MAINS	18-INCH WATER MAINS	VALVE	
10-INCH WATER MAINS	20-INCH WATER MAINS	BOUNDARY OF HIGH/LOW SERVICE AREA	MARSH, SWAMP OR WETLAND
12-INCH WATER MAINS	24-INCH WATER MAINS	RAILROAD TRACKS	BROOK, STREAM OR RIVER

SCALE 1" = 1000'

500 0 1000 2000

REVISED TO: APRIL 2006

TOWN OF HOLDEN, MASSACHUSETTS

WATER MAIN REHABILITATION MAP

PROJECT NO. 0375-24646
FILE NAMEMASTERPLANMAP.DWG

MAP NO.
2