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1.0 INTRODUCTION

This report presents the results of our tests, investigations, calculations, and studies of the water distribution facilities of the Sudbury Water District. A water system hydraulic model was developed by collecting and reviewing various data provided by the District, including Annual Statistical Reports, water usage, and maps of the existing water system. This report was prepared in accordance with our agreement with the District, summarized as follows:

- Utilize existing studies, reports, utility and field data, and records to develop a hydraulic model of the Sudbury Water District Water System.
- Conduct field tests to calibrate the water system hydraulic model
- Identify system deficiencies using available fire flow, static pressures, and pipe reliability as a basis.
- Identify improvements to address system deficiencies identified by the computer modeling analysis.
- Determine the impact that the water system improvements will have on the water system.
- Develop a prioritized Capital Project List and budget for water system improvements.

1.1 BACKGROUND

The Town of Sudbury is located in Middlesex County, Massachusetts, approximately 20 miles west of Boston. The Town has a population of 18,317 and is primarily a residential community consisting of single family homes in large subdivisions. The entire population is served by the Sudbury Water District. Commercial growth has been restricted to the Town's main road, US Route 20, and significant portions of open space have been preserved throughout the Town. The District has seen a relatively steady demand over the past five years of Annual Statistical Report data, and is anticipated to continue that trend.

1.1.1 Water Supply

The Sudbury Water District has nine (9) active gravel packed wells that supply the entire water system. Well No. 1 has been abandoned due to salt contamination caused by nearby highway department storage. A combined capacity of 7.6 MGD of water is available to pump from the nine wells; however, the system is not designed to operate all the wells simultaneously. The wells are located within the Raymond Road Aquifer (Well Nos. 2A, 4, 6, 7 and 9), Hope Brook Aquifer (Well Nos. 3A, 8A, 10), and an aquifer located in the northeast part of town (Well No. 5).
1.1.2 Distribution Storage Facilities

Distribution storage serves to maintain system pressure by supplying local water demands during periods of peak consumption. It helps to meet hourly demand fluctuations, minimizing changes in flow rates through supply sources. Storage helps to meet required fire flows and it provides a volume of water for other emergencies such as a pipeline break or mechanical equipment malfunction. Storage, when properly located, helps to equalize pressures throughout the system.

It is necessary to maintain storage levels as near to full as possible in order to maintain maximum available pressure in the distribution system, and to maximize fire flow availability. However, it is also important to allow the tank levels to fluctuate to minimize stagnant conditions and maintain water quality.

The Sudbury Water District relies on four (4) ground level storage facilities that combine for a total capacity of 6.3 MG. Two storage tanks located on Willis Hill provide a significant majority of the overall capacity. A 1.0 MG storage tank is located at the end of Bigelow Drive, and a 0.3 MG tank is located on Goodman Hill. The following Table 1.1 presents the existing storage facilities and capacities.

<table>
<thead>
<tr>
<th>Tank Location</th>
<th>Storage Type</th>
<th>Installation Year</th>
<th>Material</th>
<th>*Tank Height</th>
<th>Tank Overflow</th>
<th>Storage Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willis Hill</td>
<td>Ground Level</td>
<td>1971</td>
<td>Steel</td>
<td>45.5'</td>
<td>380.5'</td>
<td>3.0 MG</td>
</tr>
<tr>
<td>Willis Hill</td>
<td>Ground Level</td>
<td>2007</td>
<td>Glass Lined Steel</td>
<td>45.0'</td>
<td>380.5'</td>
<td>2.0 MG</td>
</tr>
<tr>
<td>Bigelow Hill</td>
<td>Ground Level</td>
<td>1986</td>
<td>Steel</td>
<td>31.5'</td>
<td>*388'</td>
<td>1.0 MG</td>
</tr>
<tr>
<td>Goodman’s Hill</td>
<td>Ground Level</td>
<td>1936</td>
<td>Steel</td>
<td>28.0'</td>
<td>*388'</td>
<td>0.3 MG</td>
</tr>
</tbody>
</table>

*Storage facility information obtained from November 2004 report, Updated Water Distribution Facilities Analysis, H2O Engineering Consulting Associates.

1.1.3 Distribution System

According to the 2015 Annual Statistical Report, the distribution system serves 18,317 people through 5,986 service connections. The distribution system includes approximately 147 miles of water main comprised of asbestos cement, lined ductile iron, unlined cast iron, and PVC pipe.
The approximate overall lengths of each diameter pipe and pipe material are summarized in Table 1.2 and Table 1.3.

**Table 1.2 - Distribution Pipe Diameter**

<table>
<thead>
<tr>
<th>Pipe Diameter (in)</th>
<th>Length (mi)</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.1</td>
<td>0.1%</td>
</tr>
<tr>
<td>6</td>
<td>10.9</td>
<td>7.5%</td>
</tr>
<tr>
<td>8</td>
<td>80.4</td>
<td>54.8%</td>
</tr>
<tr>
<td>10</td>
<td>35.7</td>
<td>24.3%</td>
</tr>
<tr>
<td>12</td>
<td>16.3</td>
<td>11.1%</td>
</tr>
<tr>
<td>16</td>
<td>3.2</td>
<td>2.2%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>146.6</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

**Table 1.3 - Distribution Pipe Material**

<table>
<thead>
<tr>
<th>Pipe Material</th>
<th>Length (mi)</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ductile Iron</td>
<td>34.0</td>
<td>23.2%</td>
</tr>
<tr>
<td>Asbestos Cement</td>
<td>97.8</td>
<td>66.7%</td>
</tr>
<tr>
<td>PVC</td>
<td>9.4</td>
<td>6.4%</td>
</tr>
<tr>
<td>Unlined Cast Iron</td>
<td>3.1</td>
<td>2.1%</td>
</tr>
<tr>
<td>Unknown</td>
<td>2.3</td>
<td>1.6%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>146.6</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

Most of the water system pipe was installed from the 1950s to 1980s. During this time the population served by the District experienced large growth from 2,596 to 14,000 people. Asbestos cement was the primary material installed during this period of growth and consequently makes up the majority of the District's water system. A summary of pipe installation year is presented below in Table 1.4.
Table 1.4 - Year of Installation

<table>
<thead>
<tr>
<th>Installation Year</th>
<th>Length (mi)</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1950s</td>
<td>0.2</td>
<td>0.2%</td>
</tr>
<tr>
<td>1950s</td>
<td>18.3</td>
<td>12.5%</td>
</tr>
<tr>
<td>1960s</td>
<td>58.0</td>
<td>39.5%</td>
</tr>
<tr>
<td>1970s</td>
<td>14.7</td>
<td>10.0%</td>
</tr>
<tr>
<td>1980s</td>
<td>16.5</td>
<td>11.2%</td>
</tr>
<tr>
<td>1990s</td>
<td>13.6</td>
<td>9.3%</td>
</tr>
<tr>
<td>2000s</td>
<td>5.5</td>
<td>3.8%</td>
</tr>
<tr>
<td>2010s</td>
<td>5.2</td>
<td>3.6%</td>
</tr>
<tr>
<td>Unknown</td>
<td>14.7</td>
<td>10.0%</td>
</tr>
<tr>
<td>Total</td>
<td>146.6</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

1.1.4 Water Consumption

Water consumption is typically comprised of residential, commercial, and industrial demands as well as unaccounted for water (UAW). A breakdown of demand types and a brief description of each are shown below:

Residential: Water used in residences and apartments for drinking, bathing, sanitation, recreation and lawn watering;

Commercial: Water used in restaurants, service stations and commercial establishments;

Agricultural: Farms, garden center;

Industrial: Water used in manufacturing and warehousing facilities;

Municipal: Hydrant flushing, water treatment plant use, firefighting, schools municipal buildings, churches, playing fields;

Unaccounted for: Water that includes all unmetered uses, leaks, water main breaks.

The Town of Sudbury consists of mainly residential homes in large subdivisions, and consequently the demand in the system is heavily impacted by residential usage. Table 1.5 below presents the percentage of water use by each user category.
Table 1.5 - Water Use by Category

<table>
<thead>
<tr>
<th>Water Use</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>80.3%</td>
</tr>
<tr>
<td>Commercial</td>
<td>12.3%</td>
</tr>
<tr>
<td>Agricultural</td>
<td>2.0%</td>
</tr>
<tr>
<td>Industrial</td>
<td>1.7%</td>
</tr>
<tr>
<td>Municipal</td>
<td>3.4%</td>
</tr>
<tr>
<td>Other</td>
<td>0.3%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Population, land use restrictions and water consumption habits collectively influence the pattern of residential water use. Since it is primarily dependent on the population served, domestic water consumption is often expressed in terms of gallons per capita per day (gpcd). Table 1.6 presents the residential use in gpcd over the past six years.

Table 1.6 - Residential Water Usage

<table>
<thead>
<tr>
<th>Year</th>
<th>MG*</th>
<th>GPD*</th>
<th>Population Served</th>
<th>GPCD</th>
<th>% of Total Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>460.365</td>
<td>1,261,274</td>
<td>18,015</td>
<td>70.0</td>
<td>81.4%</td>
</tr>
<tr>
<td>2011</td>
<td>405.339</td>
<td>1,110,518</td>
<td>18,160</td>
<td>61.2</td>
<td>78.2%</td>
</tr>
<tr>
<td>2012</td>
<td>444.315</td>
<td>1,217,301</td>
<td>18,103</td>
<td>67.2</td>
<td>81.6%</td>
</tr>
<tr>
<td>2013</td>
<td>421.336</td>
<td>1,154,345</td>
<td>18,317</td>
<td>63.0</td>
<td>78.6%</td>
</tr>
<tr>
<td>2014</td>
<td>408.748</td>
<td>1,119,858</td>
<td>18,317</td>
<td>61.1</td>
<td>78.1%</td>
</tr>
<tr>
<td>2015</td>
<td>458.701</td>
<td>1,256,715</td>
<td>18,317</td>
<td>68.6</td>
<td>83.8%</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>433.134</strong></td>
<td><strong>1,186,668</strong></td>
<td><strong>18,205</strong></td>
<td><strong>65.2</strong></td>
<td><strong>80.3%</strong></td>
</tr>
</tbody>
</table>

*Data taken from Sudbury Water District’s Annual Statistical Reports

As shown in the Table 1.6, the per capita residential consumption rate has varied from 61 to 70 gallons per day with an average of approximately 65 gpcd. The Sudbury Water District has seen a relatively steady residential demand. This has been attributed to slow growth, restricted water use and public education. The Table below presents average and maximum day demands for the past five (6) years.
Overall the District has seen relatively stable demand conditions. For this study the demand conditions for 2015 were used to determine water system improvements. The population growth has stabilized and any new large user demands will be analyzed independently.
2.0 HYDRAULIC MODEL

2.1 INTRODUCTION

A hydraulic model was developed to analyze the water distribution system of the Sudbury Water District under existing conditions. Hydraulic models use the information input to perform calculations that approximate head loss in the model pipes and predict pressures at model nodes. Typically, models can be run in steady state mode, a snapshot of the system at any point in given time, or in extended period mode, a series of snapshots taken over a specified time frame. A properly calibrated hydraulic model has many benefits for the planning and operation of a water system. Some of these include:

- Simulate, analyze, and optimize improvements prior to constructing them
- Simulate and refine system operational changes prior to implementing them
- Determine system’s adequacy for firefighting and storage
- Emergency response planning

The Sudbury water system model was created in WaterCAD, a modeling software developed and distributed by Bentley Systems. Pipe data required by the model includes diameter, length, material, and estimated Hazen-Williams “C” value. Pipe C-values are numbers that are assigned to each pipe that are used to represent the condition of the interior surface of the pipe wall. Nodes, which are locations in the model where pipes intersect, end or change characteristics, are also added into the model. Data for nodes include demands and elevations. Boundary nodes are locations in the model where the hydraulic gradeline (ground elevation plus water pressure in feet) is set. Boundary nodes typically include tanks, pumps and metered supply connections. Water consumption data are used to allocate demands across the system. Scenarios to simulate average day and maximum day demand conditions were developed using historical demand data. Information for the hydraulic model was gathered from the Department’s records, GIS data collection, and previous water system reports.

2.2 MODEL INPUT DATA

In order to create and calibrate a hydraulic model, information on the network and boundary conditions first needs to be established. A previously developed water distribution map was used as the framework for generating the water system model. The map, along with a water system asset database provided by the District, was first used to develop a pipe network in a GIS environment. The water system data in GIS includes pipe geometry, diameter, installation year, material, and lengths of pipe. GPS equipment was then used to locate 987 hydrants, 915 hydrant valves and 1,052 main line valves throughout the entire system. The updated water system maps
were reviewed by the District, and additional changes were completed. After the water system was recreated in a GIS environment, the data was imported into the hydraulic model software.

### 2.2.1 Pipe Network

The water distribution system includes approximately 147 miles of pipe with sizes up to 16-inch diameter. The GIS network created from existing data and new GPS collected data was used to create the pipe network in the hydraulic model. Hydrants and valves were also imported from the existing GIS information and applied to the pipe network. A water distribution map is included in Appendix A. Information on the installation year and pipe material was used to determine the probable condition of the existing water mains. Nodes were created where the pipes intersect, end, or change characteristics. Topographic information applied to the nodes was modeled using existing contour data available through the State of Massachusetts GIS website.

### 2.2.2 Demands

Water usage data by parcel were provided by the District. The demands were spread throughout the nodes in the model using a polygon method. A network of polygons is created using the hydraulic model software. Each water billing account is assigned within a polygon based on proximity. Water billing accounts within a particular polygon are assigned to the same demand node in the hydraulic model. This results in higher demands near the large users along Boston Post Road and lower demands at the extremities. Scenarios to simulate average day and maximum day demand conditions were developed using the 2015 ASR data.

### 2.2.3 Supply Sources

Existing SCADA data were used to determine average flow rates from each water treatment facility. For the average day hydraulic model conditions the Raymond Road Water Treatment Plant (RRWTP), Hop Brook Treatment Plant, and Well 6 were online. The approximate flow rates at these locations are shown below in Table 2.1. In order to simplify the hydraulic model, the wells supplying the system were modeled as inflow nodes. For the average day analysis it was assumed that all active well pumps were online. For fire flow analyses a maximum day demand with the wells offline was simulated.

<table>
<thead>
<tr>
<th>Supply Facility</th>
<th>Flow Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raymond Road Water Treatment Plant</td>
<td>1200 gpm</td>
</tr>
<tr>
<td>Hop Brook Water Treatment Plant</td>
<td>875 gpm</td>
</tr>
<tr>
<td>Well 6 Treatment</td>
<td>515 gpm</td>
</tr>
</tbody>
</table>
2.2.4 Storage

Existing data were also used to determine the tank levels prior to calibration. Tank starting levels for calibration were determined using the height from the base of tank, provided by the SCADA, and existing elevation data provided by State of Massachusetts GIS.

2.3 FIELD COLLECTED DATA

Hydrant flow tests were conducted to determine the available fire flow at a particular location in the water distribution system. To properly conduct a hydrant flow test a pitot gauge is required on the hydrant to be flowed, and a pressure gauge is required on an additional hydrant. The pitot gauge provides a discharge pressure that can be converted to approximate flow. The pressure gauge will be installed on a hydrant downstream of the flowing hydrant. A static pressure reading is obtained before the start of the test, and a residual pressure reading is taken during the flow test after the pressure has stabilized. An available flow while maintaining 20 psi pressure at the gauge hydrant can be determined using the recorded information.

The hydrant flow tests, while providing valuable information on available fire flow, are also used to calibrate a water system hydraulic model. Static and residual pressures in the field are compared to the modeled values under identical fire flow conditions. The model is adjusted to mimic the results from the fire flow field condition. During the flow tests data loggers that record system pressure were placed at key locations throughout the Town. These additional data points help to further calibrate the water system hydraulic model.

Twenty (20) hydrant flow tests were conducted on October 14, 2016 and October 15, 2016 and were used to calibrate the hydraulic model. Initial hydraulic gradeline and flow conditions at the system storage tanks and wells were obtained from the Sudbury Water District SCADA system. Table 2.2 presents the results of the hydrant flow tests. Flow test locations are shown on the hydrant flow test locations map included in Appendix B.
### Table 2.2 - Field Fire Flow Results

<table>
<thead>
<tr>
<th>Flow Test No.</th>
<th>Flow Test Location</th>
<th>Static Pressure (psi)</th>
<th>Residual Pressure (psi)</th>
<th>Calculated Discharge (gpm)</th>
<th>Calculated Available Flow at 20 psi (gpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Powder Mill at Singing Hill Rd.</td>
<td>74</td>
<td>70</td>
<td>1,267</td>
<td>5,165</td>
</tr>
<tr>
<td>2</td>
<td>North Rd. east of Anthony Dr.</td>
<td>79</td>
<td>75</td>
<td>1,061</td>
<td>4,539</td>
</tr>
<tr>
<td>3</td>
<td>Longfellow Rd. at Harvard Dr.</td>
<td>80</td>
<td>73</td>
<td>1,256</td>
<td>4,006</td>
</tr>
<tr>
<td>4</td>
<td>Willis Rd. at Loker Rd.</td>
<td>78</td>
<td>74</td>
<td>1,321</td>
<td>5,599</td>
</tr>
<tr>
<td>5</td>
<td>Marlborough Rd. at Morse Rd.</td>
<td>84</td>
<td>83</td>
<td>1,353</td>
<td>12,781</td>
</tr>
<tr>
<td>6</td>
<td>Birchwood Ave. at Great Lake Dr.</td>
<td>81</td>
<td>74</td>
<td>1,138</td>
<td>3,663</td>
</tr>
<tr>
<td>7</td>
<td>Baldwin Dr. at Mark Ln.</td>
<td>83</td>
<td>82</td>
<td>1,363</td>
<td>12,770</td>
</tr>
<tr>
<td>8</td>
<td>Hudson Rd. at Crestview Dr.</td>
<td>92</td>
<td>84</td>
<td>1,256</td>
<td>4,113</td>
</tr>
<tr>
<td>9</td>
<td>158 Newbridge Rd.</td>
<td>91</td>
<td>87</td>
<td>1,163</td>
<td>5,495</td>
</tr>
<tr>
<td>10</td>
<td>Pine St. at Winter St.</td>
<td>90</td>
<td>85</td>
<td>1,267</td>
<td>5,268</td>
</tr>
<tr>
<td>11</td>
<td>Peckham Rd. at Whispering Pine Rd.</td>
<td>96</td>
<td>89</td>
<td>1,126</td>
<td>4,080</td>
</tr>
<tr>
<td>12A</td>
<td>Colonial Rd. at Homestead St.</td>
<td>94</td>
<td>87</td>
<td>1,150</td>
<td>4,110</td>
</tr>
<tr>
<td>13</td>
<td>Rice Rd. at Fieldstone Farm</td>
<td>66</td>
<td>24</td>
<td>503</td>
<td>529</td>
</tr>
<tr>
<td>14</td>
<td>French Rd. at Garrison Rd.</td>
<td>85</td>
<td>81</td>
<td>1,244</td>
<td>5,608</td>
</tr>
<tr>
<td>15</td>
<td>Wayside Inn Mill</td>
<td>81</td>
<td>75</td>
<td>1,222</td>
<td>4,274</td>
</tr>
<tr>
<td>16</td>
<td>Pond Rd. at Elliot Rd.</td>
<td>95</td>
<td>90</td>
<td>1,256</td>
<td>5,419</td>
</tr>
<tr>
<td>17</td>
<td>71 Concord Rd. north of Confidence Way</td>
<td>98</td>
<td>93</td>
<td>1,233</td>
<td>5,436</td>
</tr>
<tr>
<td>18</td>
<td>Goodman's Hill Rd. south of Walker Farm Rd.</td>
<td>109</td>
<td>101</td>
<td>1,472</td>
<td>5,408</td>
</tr>
<tr>
<td>19</td>
<td>Stockfarm Rd. at Christopher Ln.</td>
<td>101</td>
<td>88</td>
<td>1,424</td>
<td>3,824</td>
</tr>
<tr>
<td>20</td>
<td>Cider Mill Rd. west of Rambling Rd.</td>
<td>100</td>
<td>93</td>
<td>1,321</td>
<td>4,924</td>
</tr>
</tbody>
</table>

Note: Shaded box indicates deficient fire flow based on lowest required fire flow. Fire flow requirements estimated by Stantec based on nearby ISO fire flow requirements; most residential areas were assigned conservative requirement of 750 gpm even if homes are greater than 100 feet apart.

The flow tests results indicate that the Sudbury water system is very strong. Only one location was determined to be deficient. This location is located on a long dead end 8-inch cast iron pipe.

### 2.4 MODEL CALIBRATION

#### 2.4.1 Methodologies

Pipe C-values are numbers that are assigned to each pipe that are used to represent the condition of the interior surface of the pipe wall (resistance to friction). While the exact C-value for each pipe is unknown, assumptions can be made based on pipe material and the
installation year. The C-values assumed for the initial model, prior to calibration, is presented in Table 2.3.

### Table 2.3 - Estimated C-value for Existing Water Main

<table>
<thead>
<tr>
<th>Year</th>
<th>AC</th>
<th>CI</th>
<th>DI</th>
<th>PVC</th>
<th>UNK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1930's</td>
<td>-</td>
<td>30</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1940's</td>
<td>-</td>
<td>40</td>
<td>70</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1950's</td>
<td>80</td>
<td>50</td>
<td>70</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1960's</td>
<td>90</td>
<td>60</td>
<td>80</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1970's</td>
<td>100</td>
<td>70</td>
<td>90</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1980's</td>
<td>110</td>
<td>80</td>
<td>100</td>
<td>120</td>
<td>-</td>
</tr>
<tr>
<td>1990's</td>
<td>120</td>
<td>90</td>
<td>110</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2000's</td>
<td>-</td>
<td>-</td>
<td>120</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2010's</td>
<td>-</td>
<td>-</td>
<td>130</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>UNK</td>
<td>100</td>
<td>60</td>
<td>100</td>
<td>120</td>
<td>80</td>
</tr>
</tbody>
</table>

Once all data necessary to represent the water system was compiled in the model, the model was calibrated. Data collected during the hydrant flow test program was used as the basis for the calibration. Calibration involves simulating each hydrant flow test in the computer model and making adjustments or corrections to the model data until the model results are within a reasonable range to the flows and pressures that were recorded during the field tests. Typically, boundary conditions and pipe C-values are adjusted when calibrating the model.

#### 2.4.2 Calibration Results

The hydraulic model was first run under static conditions in order to verify the general system configuration, demand allocation and elevations. Once the model was verified under static conditions, each flow test was run separately in the model and residual pressures determined by the model were compared to actual readings taken in the field. For each simulation, residual pressures at the gauge hydrant and pressure loggers were compared to model calculated values.

Pipe C-values were then adjusted in the model and simulations were repeated until the model calculated pressures drops were within about 3 pounds per square inch (psi) of the field collected pressures drops. The model results indicated that three hydrant flow tests could not be calibrated within 3 psi of the field pressure drop. The hydraulic model calibrates results are shown in Table 2.4.
Table 2.4 - Hydraulic Model Calibration Results

<table>
<thead>
<tr>
<th>Flow Test</th>
<th>Location</th>
<th>Field Pressure (psi)</th>
<th>Model Pressure (psi)</th>
<th>Pressure Drop (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Static</td>
<td>Residual</td>
<td>Static</td>
<td>Residual</td>
</tr>
<tr>
<td>1</td>
<td>Powder Mill at Singing Hill Rd.</td>
<td>74</td>
<td>70</td>
<td>72.4</td>
</tr>
<tr>
<td>2</td>
<td>North Rd. east of Anthony Dr.</td>
<td>79</td>
<td>75</td>
<td>78.9</td>
</tr>
<tr>
<td>3</td>
<td>Longfellow Rd. at Harvard Dr.</td>
<td>80</td>
<td>73</td>
<td>75.8</td>
</tr>
<tr>
<td>4</td>
<td>Willis Rd. at Loker Rd.</td>
<td>78</td>
<td>74</td>
<td>75.2</td>
</tr>
<tr>
<td>5</td>
<td>Marlborough Rd. at Morse Rd.</td>
<td>84</td>
<td>83</td>
<td>82.8</td>
</tr>
<tr>
<td>6</td>
<td>Birchwood Ave. at Great Lake Dr.</td>
<td>81</td>
<td>74</td>
<td>76.5</td>
</tr>
<tr>
<td>7</td>
<td>Baldwin Dr. at Mark Ln.</td>
<td>83</td>
<td>82</td>
<td>79.0</td>
</tr>
<tr>
<td>8</td>
<td>Hudson Rd. at Crestview Dr.</td>
<td>92</td>
<td>84</td>
<td>89.6</td>
</tr>
<tr>
<td>9</td>
<td>158 Newbridge Rd.</td>
<td>91</td>
<td>87</td>
<td>89.4</td>
</tr>
<tr>
<td>10</td>
<td>Pine St. at Winter St.</td>
<td>90</td>
<td>85</td>
<td>89.0</td>
</tr>
<tr>
<td>11</td>
<td>Peakham Rd. at Whispering Pine Rd.</td>
<td>96</td>
<td>89</td>
<td>91.9</td>
</tr>
<tr>
<td>12A</td>
<td>Colonial Rd. at Homestead St.</td>
<td>94</td>
<td>87</td>
<td>88.2</td>
</tr>
<tr>
<td>13</td>
<td>Rice Rd. at Fieldstone Farm</td>
<td>66</td>
<td>24</td>
<td>60.3</td>
</tr>
<tr>
<td>14</td>
<td>French Rd. at Garrison Rd.</td>
<td>85</td>
<td>81</td>
<td>80.1</td>
</tr>
<tr>
<td>15</td>
<td>Wayside Inn Mill</td>
<td>81</td>
<td>75</td>
<td>74.0</td>
</tr>
<tr>
<td>16</td>
<td>Pond Rd. at Elliot Rd.</td>
<td>95</td>
<td>90</td>
<td>92.2</td>
</tr>
<tr>
<td>17</td>
<td>71 Concord Rd. north of Confidence Way</td>
<td>98</td>
<td>93</td>
<td>95.0</td>
</tr>
<tr>
<td>18</td>
<td>Goodman’s Hill Rd. south of Walker Farm Rd.</td>
<td>109</td>
<td>101</td>
<td>106.1</td>
</tr>
<tr>
<td>19</td>
<td>Stockfarm Rd. at Christopher Ln.</td>
<td>101</td>
<td>88</td>
<td>96.7</td>
</tr>
<tr>
<td>20</td>
<td>Cider Mill Rd. west of Rambling Rd.</td>
<td>100</td>
<td>93</td>
<td>96.0</td>
</tr>
</tbody>
</table>

* Unable to reach calibration goal

Three locations were unable to be calibrated within the 3 psi limit goal. The headloss predicted by the model results is greater than the headloss observed in the field. This is most likely due to discrepancies in the field collected discharge data. If the discharge flow was lower than reported in the field, the model would more closely match the field data. The locations unable to be calibrated are localized to the most northern and southeastern areas of Town. Overall the hydraulic model represents the existing system very well with the exception of those three locations. With a calibrated hydraulic model, water system improvements will be analyzed throughout the distribution system.
3.0 ADEQUACY OF DISTRIBUTION STORAGE

The minimum volume of water required for storage is dependent upon the equalizing storage requirement plus storage volume needed for fire protection.

3.1 EQUALIZING STORAGE

Equalizing storage, the volume of water necessary to satisfy hourly fluctuations in water consumption, generally amounts to about 20 percent of the total water consumption on any given day for systems with typical residential and industrial demand percentages. The current equalizing storage required is 0.345 MG or 20% of the average maximum day consumption (1.723 MGD).

3.2 FIRE FLOW STORAGE

The Insurance Services Office (ISO) grades the overall fire fighting capabilities of a community by evaluating a number of factors, including the volume of water available in storage. Section 501 of the ISO Fire Suppression Rating Schedule defines a community’s Basic Fire Flow as the highest site specific fire flow, but not greater than 3,500 gpm for a duration of 3 hours. The Basic Fire Flow is used to determine the adequacy of water supply and distribution storage facilities. Based on the hydrant flow tests performed by the ISO in 2014, the Basic Fire Flow for the Water District is 3,500 gpm. The fire flow requirement for the Water District is therefore based on 3,500 gpm, for a three-hour duration, or 630,000 gallons.

3.3 TOTAL STORAGE REQUIREMENTS

The minimum water storage requirement for the Sudbury Water District is the sum of the equalizing storage and the fire flow requirement, or 975,000 gallons.

3.4 USEABLE STORAGE

Total useable storage is based upon the volume of water above the level in the tanks required to maintain a minimum pressure of 20 psi (approximately 46 feet of head) for fire protection, at all locations within the vicinity of each storage facility. The system has a maximum service elevation of 393 feet on Puritan Lane, southeast of Goodman’s Hill tank. In order to provide 20 psi at an elevation of 393 feet, the hydraulic gradeline would have to be at 440 feet. All storage tanks have an overflow elevation of 388 feet or less, therefore none of the storage is usable at this elevation. Based on the tank overflow of 388, only homes at or below elevation 342 feet would receive 20 psi when the storage tanks are full. There are two other areas in the water distribution system which experience pressures below 20 psi during typical tank fluctuation. Hillside Place is located at the crest of a hill on Pokonoket Avenue. Homes located at the crest of the hill are at a maximum elevation of 334 feet. These homes experience pressures that range
from 17 to 24 psi. Additional homes located on Bigelow Drive and Brimstone Lane are in close proximity to the Bigelow Storage Tank. These locations reach a maximum elevation of 383 feet and experience pressures well below 20 psi. The high elevation areas request special consideration and should be addressed separately.

Without considering those homes, the highest elevation served by the water system would be those at elevation 324 feet. With a highest elevation of 324 feet, the total usable volume available from the water storage tanks would be 1.959 MG. The Water District does not currently require any additional storage however; homes located above elevation 342 feet will require special consideration to address operating pressure and fire protection requirements. This will be addressed in Section 4.1.
4.0 Adequacy of Distribution System Piping

4.1 Pressure Requirements

The distribution system should be capable of delivering the maximum demand, including fire flows, while maintaining suitable pressures throughout the service area. The Department of Environmental Protection’s Guidelines for Public Water Systems recommend that a system maintain a minimum working pressure of 35 pounds per square inch (psi) in the distribution system under normal demand conditions. When fire flows are considered, the DEP recommends that a system maintain a minimum pressure of 20 psi everywhere in the system.

There are three areas in the Water District that have low-pressure issues. These locations include the high elevation areas around the Goodman’s Hill Tank in the eastern area of the Town and the area around the Bigelow Tank in the southwestern portion of Town. Figure 4.1 and Figure 4.2 identify the areas of The Water District where low pressure is experienced.
Figure 4.2 - High Elevation Area 2
Pressures are below 20 psi in the Puritan Lane location near the Goodman’s Hill Tank. In some areas, negative pressures would be seen with the storage tank full. Pressures below 20 psi are observed at all three locations during typical tank fluctuation. There are currently individual booster pumps on some of the high elevation homes that remedy the low pressures. However, it is possible there are still homes that experience low pressures during normal operating conditions. Low pressures also affect available fire flows in the high elevation areas and as a result, there is little to no fire flow at many of these locations. There are three options to solve these low pressure problems:

- **Option 1:** Creation of a high service area with a new storage tank and pump station
- **Option 2:** Creation of a high service area with a booster pump station and fire pump
- **Option 3:** Individual booster pumps on residential water service lines.

These options are summarized in detail below.

**Option 1: Create New High Service Area with Storage Tank & Pump Station**

A new high service area could be created to solve the low pressure problems in the Puritan Lane area. A section of the distribution system in that area could be isolated from the remaining distribution system through the installation of division gates and a pressure reducing valve to maintain a connection to the main service area. In order to boost the pressure in this area, a booster pumping station would be constructed along Goodman’s Hill Road approximately 400 feet north of the 12-inch tank supply pipe. The new booster pump station would pump to a new tank at an elevation of approximately 475 feet. The tank would be located at the existing Goodman Hill Tank site or at another location. The tank overflow elevation would increase pressures by approximately 40 psi. The Hillside Place low pressure area would not be included in the new high service area. In order to encompass the Hillside Place high elevation location, other areas of the required high service zone would experience pressures well above 100 psi. The proposed high service area and associated improvements are presented in Figure 4.3 below.
Figure 4.3 – Proposed High Service Area (Option 1)
Adequacy of Distribution System Piping
January 9, 2017

Advantages:
- Provide fire protection to high service area through gravity from new elevated storage tank
- Eliminate majority of the pressure deficient homes
- Minimal decrease in available fire flow outside of the high service area

Disadvantages:
- Additional operational and maintenance from pressure reducing valves and new pumping station
- Does not provide a solution for all of the pressure deficient areas
- Creation of dead ends at high service divisions
- Most costly option at $2,366,000

Option 2: Create New High Service Area with Pump Station

Similar to Option 1, Option 2 also includes the creation of an isolated high service area for the Puritan Lane location through the installation of division gates and pressure reducing valves. A booster pump station would also be required to boost pressures in this area. The same high service area would be created as proposed in Option 1. This booster pump would include variable frequency drives in order to maintain pressures in the high service area since this option does not include the construction of a new tank. In addition to domestic booster pumps, a fire pump with a capacity of 750 gpm would also be installed in order to meet the fire protection requirements within this area. The existing Goodman Hill Tank would be removed from service.

Advantages:
- Provide fire protection to high service area through fire pump installed in new booster pump station
- Eliminate majority of the pressure deficient homes

Disadvantages:
- Additional operational and maintenance from pressure reducing valves and new pumping station
- No tank to provide fire flow greater than 750 gpm within the service area. Total reliance on pump and suction pipe.
Option 3: Install Individual Booster Pumps on Residential Water Service Lines

The third option includes the installation of small booster pumps on the service lines in the basements of the homes that are currently receiving inadequate pressures. The booster pumps require a check valve to ensure no reverse flow is experienced during a fire. These pumps could be installed instead of larger scale distribution system improvements resulting in a significant cost savings. There are approximately twelve (12) homes that typically operate at or below 20 psi. With the installation of small booster pumps, these homes would have adequate pressure and The Water District could allow the tanks to fluctuate within the recommended 20% range depending on the tank height. For a cost of approximately $2,500 per home, these pumps could be installed within the basements of these homes. Many of the homes in the high elevation areas have booster pumps previously installed and would not need an additional pump. Check valves will have to be installed in homes that have had the booster pump installed without a check valve.

Advantages:

- Least costly option
- Storage tanks can fluctuate 20% while homeowners still have adequate pressure

Disadvantages:

- Fire protection for these areas will still require a pumper fire truck.

4.2 Fire Flow Requirements

The Insurance Services Office (ISO) grades the overall fire fighting capabilities of a community by evaluating a number of factors, including the fire flows available at a residual pressure of 20 psi. Several criteria go into determining the Needed Fire Flows, as defined by ISO. They include building size, type of occupancy, materials of construction, proximity to other buildings, and the existence of sprinklers. Needed fire flows are site specific; however, according to Section 340 of the ISO Fire Suppression Rating Schedule, the Needed Fire Flow shall not exceed 12,000 gpm or be less than 500 gpm. The ISO has simplified the procedure for determining the Needed Fire Flows in areas of 1 and 2 family dwellings, not exceeding two stories in height. Table 4.1 presents these criteria.
Table 4.1 - ISO Fire Flow Requirements

<table>
<thead>
<tr>
<th>Distance Between buildings</th>
<th>Required Fire Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 100 feet</td>
<td>500 gpm</td>
</tr>
<tr>
<td>31 - 100 feet</td>
<td>750 gpm</td>
</tr>
<tr>
<td>11 - 30 feet</td>
<td>1,000 gpm</td>
</tr>
<tr>
<td>10 feet or less</td>
<td>1,500 gpm</td>
</tr>
</tbody>
</table>

In addition, the ISO criteria for other habitable buildings is a maximum of 3,500 gpm. Where specific requirements based on ISO criteria have not been developed, Stantec has adopted an estimated fire flow based on the closest ISO location and corresponding requirement. Industrial and commercial areas generally have higher requirements than residential areas. Additionally, ISO has provided specific requirements at other locations within The Water District such as near schools, warehouses, and heavily populated areas.

Needed fire flows at specific locations are used to determine the adequacy of the distribution piping. Fire flows generally result in higher and more localized flow rates in the piping leading to the fire flow location. The higher flow rates result in greater headloss and decreases in system pressures. Deficient pipes are easily identified and localized improvements can then be identified and evaluated.

The most recent flow tests by ISO were conducted on November 19, 2014. Although these tests were conducted recently, Stantec does not believe the results are accurate or reliable. Many of the static pressures recorded were well above 100 psi, even exceeding 150 psi. These pressures are not possible based on ground elevation and storage tank levels. Stantec used the ISO fire flow requirements but not the fire flow results for this analysis. The ISO flow tests are attached as Appendix A.

4.3 Hydrant Flow Tests

Hydrant flow tests and observations of system pressures were conducted on October 14 and 15, 2016 by the District and Stantec personnel. Flow test locations are also shown on the distribution map located in Appendix A. The purpose of these tests was to observe normal system operation as well as system operation under stress, that is, under various fire flow conditions. The results of these tests were used to assist in the calibration of the computer model of the distribution system. Table 4.2 presents the pressures and flows recorded during those flow tests as well as the estimated ISO required fire flow and fire flow available at a residual of 20 psi for the 2016 hydrant flow tests.
Table 4.2 - Flow Tests Field Results

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Powder Mill at Singing Hill Rd.</td>
<td>74</td>
<td>70</td>
<td>1,267</td>
<td>2,250</td>
<td>5,165</td>
</tr>
<tr>
<td>2</td>
<td>North Rd. east of Anthony Dr.</td>
<td>79</td>
<td>75</td>
<td>1,061</td>
<td>2,500</td>
<td>4,539</td>
</tr>
<tr>
<td>3</td>
<td>Longfellow Rd. at Harvard Dr.</td>
<td>80</td>
<td>73</td>
<td>1,256</td>
<td>750</td>
<td>4,006</td>
</tr>
<tr>
<td>4</td>
<td>Willis Rd. at Loker Rd.</td>
<td>78</td>
<td>74</td>
<td>1,321</td>
<td>750</td>
<td>5,599</td>
</tr>
<tr>
<td>5</td>
<td>Marlborough Rd. at Morse Rd.</td>
<td>84</td>
<td>83</td>
<td>1,353</td>
<td>750</td>
<td>12,781</td>
</tr>
<tr>
<td>6</td>
<td>Birchwood Ave. at Great Lake Dr.</td>
<td>81</td>
<td>74</td>
<td>1,138</td>
<td>1,000</td>
<td>3,663</td>
</tr>
<tr>
<td>7</td>
<td>Baldwin Dr. at Mark Ln.</td>
<td>83</td>
<td>82</td>
<td>1,363</td>
<td>750</td>
<td>12,770</td>
</tr>
<tr>
<td>8</td>
<td>Hudson Dr. at Crestview Dr.</td>
<td>92</td>
<td>84</td>
<td>1,256</td>
<td>1,000</td>
<td>4,113</td>
</tr>
<tr>
<td>9</td>
<td>158 Newbridge Rd.</td>
<td>91</td>
<td>87</td>
<td>1,163</td>
<td>2,000</td>
<td>5,495</td>
</tr>
<tr>
<td>10</td>
<td>Pine St. at Winter St.</td>
<td>90</td>
<td>85</td>
<td>1,267</td>
<td>750</td>
<td>5,268</td>
</tr>
<tr>
<td>11</td>
<td>Peakham Rd. at Whispering Pine Rd.</td>
<td>96</td>
<td>89</td>
<td>1,126</td>
<td>750</td>
<td>4,080</td>
</tr>
<tr>
<td>12A</td>
<td>Colonial Rd. at Homestead St.</td>
<td>94</td>
<td>87</td>
<td>1,150</td>
<td>750</td>
<td>4,110</td>
</tr>
<tr>
<td>13</td>
<td>Rice Rd. at Fieldstone Farm</td>
<td>66</td>
<td>24</td>
<td>503</td>
<td>750</td>
<td>529*</td>
</tr>
<tr>
<td>14</td>
<td>French Rd. at Garrison Rd.</td>
<td>85</td>
<td>81</td>
<td>1,244</td>
<td>750</td>
<td>5,608</td>
</tr>
<tr>
<td>15</td>
<td>Wayside Inn Mill</td>
<td>81</td>
<td>75</td>
<td>1,222</td>
<td>3,500</td>
<td>4,274</td>
</tr>
<tr>
<td>16</td>
<td>Pond Rd. at Elliot Rd.</td>
<td>95</td>
<td>90</td>
<td>1,256</td>
<td>2,500</td>
<td>5,419</td>
</tr>
<tr>
<td>17</td>
<td>71 Concord Rd. north of Confidence Way</td>
<td>98</td>
<td>93</td>
<td>1,233</td>
<td>3,500</td>
<td>5,436</td>
</tr>
<tr>
<td>18</td>
<td>Goodman's Hill Rd. south of Walker Farm Rd.</td>
<td>109</td>
<td>101</td>
<td>1,472</td>
<td>3,500</td>
<td>5,408</td>
</tr>
<tr>
<td>19</td>
<td>Stockfarm Rd. at Christopher Ln.</td>
<td>101</td>
<td>88</td>
<td>1,424</td>
<td>750</td>
<td>3,824</td>
</tr>
<tr>
<td>20</td>
<td>Cider Mill Rd. west of Rambling Rd.</td>
<td>100</td>
<td>93</td>
<td>1,321</td>
<td>750</td>
<td>4,924</td>
</tr>
</tbody>
</table>

Note: Shaded box indicates deficient fire flow based on lowest required fire flow. Fire flow requirements estimated by Stantec based on nearby ISO fire flow requirements; most residential areas were assigned conservative requirement of 750 gpm even if homes are greater than 100 feet apart.

As shown in Table 4.2, of the 20 flow tests performed one (1) test did not meet the Needed Fire Flow based on the field testing. This illustrates the overall strength of the Sudbury Water District’s water system. The failed location is on an old 8-inch cast iron pipe positioned on a long dead end section of pipe.

Although the field results indicate high available fire flows at most flow test field locations, Stantec evaluated 20 other locations within the water system to determine available fire flows. Some of these areas include dead ends, areas of small diameter mains, areas with old or unlined cast iron pipe, and areas that require high fire flow rates.
The hydraulic model was run under a maximum day condition with tank levels 10 feet below overflow of 388 feet, and the wells in the system offline to simulate a conservative available flow condition. The ISO required fire flows were approximated based on proximity to the original ISO locations. Many of the locations evaluated are located in rural neighborhoods with smaller diameter pipes. Due to the distance between homes Stantec has chosen a conservative ISO required flow of 750 gpm. The results of the modeled flow tests are presented in Table 4.3.

One selected location, S-16, is along the same 8-inch cast iron pipe as the deficient Flow Test Flow Test 13 presented in Table 4.2. The improvement options for S-16 will also bring Flow Test 13 into compliance and are presented in Table 4.4.
### Table 4.3 - Model Results

<table>
<thead>
<tr>
<th>Flow Test No.</th>
<th>Model Junction</th>
<th>Location</th>
<th>Elevation (feet)</th>
<th>Static Pressure (psi)</th>
<th>Estimated ISO Required Flow (gpm)</th>
<th>Available Flow at 20 psi (gpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-1</td>
<td>J-1097</td>
<td>Cranberry Circle</td>
<td>189</td>
<td>79</td>
<td>750</td>
<td>940</td>
</tr>
<tr>
<td>S-2</td>
<td>J-934</td>
<td>Ford Rd at Belcher Dr</td>
<td>200</td>
<td>74</td>
<td>750</td>
<td>3,290</td>
</tr>
<tr>
<td>S-3</td>
<td>J-697</td>
<td>Willard Grant Rd at Cedar Creek Rd</td>
<td>216</td>
<td>67</td>
<td>750</td>
<td>3,520</td>
</tr>
<tr>
<td>S-4</td>
<td>J-18</td>
<td>Conwin Russell School-Broccoli</td>
<td>200</td>
<td>75</td>
<td>750</td>
<td>2,000</td>
</tr>
<tr>
<td>S-5</td>
<td>J-325</td>
<td>Arborretum Way at Cutting Ln</td>
<td>187</td>
<td>80</td>
<td>750</td>
<td>1,940</td>
</tr>
<tr>
<td>S-6</td>
<td>J-593</td>
<td>Woodmere Dr at Musket Ln</td>
<td>137</td>
<td>102</td>
<td>750</td>
<td>1,470</td>
</tr>
<tr>
<td>S-7</td>
<td>J-105</td>
<td>Concord Rd at Cail Farm Rd</td>
<td>127</td>
<td>106</td>
<td>750</td>
<td>1,550</td>
</tr>
<tr>
<td>S-8</td>
<td>J-1177</td>
<td>Lincoln-Sudbury High School</td>
<td>159</td>
<td>92</td>
<td>750</td>
<td>4,210</td>
</tr>
<tr>
<td>S-9</td>
<td>J-859</td>
<td>Birchwood Ave at Great Lake Dr</td>
<td>200</td>
<td>74</td>
<td>750</td>
<td>1,060</td>
</tr>
<tr>
<td>S-10</td>
<td>J-1066</td>
<td>Stubtoe Ln at Teakettle Ln</td>
<td>163</td>
<td>91</td>
<td>750</td>
<td>770</td>
</tr>
<tr>
<td>S-11</td>
<td>J-913</td>
<td>Poplar St at Linden Rd</td>
<td>186</td>
<td>80</td>
<td>750</td>
<td>1,970</td>
</tr>
<tr>
<td>S-12</td>
<td>J-651</td>
<td>Jarman Rd at Rolling Ln</td>
<td>154</td>
<td>94</td>
<td>750</td>
<td>2,320</td>
</tr>
<tr>
<td>S-13</td>
<td>J-317</td>
<td>Jack Pine Dr at Red Oak Dr</td>
<td>239</td>
<td>58</td>
<td>750</td>
<td>1,170</td>
</tr>
<tr>
<td>S-14</td>
<td>J-1100</td>
<td>Brimstone Ln</td>
<td>312*</td>
<td>26</td>
<td>750</td>
<td>640*</td>
</tr>
<tr>
<td>S-15</td>
<td>J-304</td>
<td>Boston Post Rd at Sudbury Fire</td>
<td>152</td>
<td>95</td>
<td>3,500</td>
<td>6,130</td>
</tr>
<tr>
<td>S-16</td>
<td>J-625</td>
<td>Old Sudbury Rd at Harvey's Farm Ln</td>
<td>213</td>
<td>69</td>
<td>750</td>
<td>390</td>
</tr>
<tr>
<td>S-17</td>
<td>J-524</td>
<td>Puritan Ln at Pilgrim's Path</td>
<td>330*</td>
<td>19</td>
<td>750</td>
<td>0*</td>
</tr>
<tr>
<td>S-18</td>
<td>J-878</td>
<td>Indian Ridge Rd at Clark Ln</td>
<td>246</td>
<td>55</td>
<td>750</td>
<td>1,550</td>
</tr>
<tr>
<td>S-19</td>
<td>J-71</td>
<td>Old County Rd at Butch Auto</td>
<td>133</td>
<td>103</td>
<td>3,500</td>
<td>1,800</td>
</tr>
<tr>
<td>S-20</td>
<td>J-656</td>
<td>Eddy St at Russet Ln</td>
<td>160</td>
<td>92</td>
<td>750</td>
<td>2,390</td>
</tr>
</tbody>
</table>

**Note:** *Starred value indicates high elevation area. Shaded box indicates deficient fire flow based on lowest required fire flow. Fire flow requirements estimated by Stantec based on nearby ISO fire flow requirements; most residential areas were assigned conservative requirement of 750 gpm even if homes are greater than 100 feet apart.*
The model results indicate that four (4) locations in the Sudbury Water Distribution system are deficient. Two locations, located on Brimstone Lane and Puritan lane, are deficient due to high ground elevation and low static pressures. The improvements for the higher elevation locations are discussed previously in Section 4.1.

Simulation Test S-16 located on Old Sudbury Road was unable to provide flows greater than 500 gpm, the minimum fire flow required by ISO. This location is along the same dead end section of 8-inch cast iron pipe as Flow Test 13 in Table 4.2. Simulation Test S-19 on Old Country Road showed a fire flow available greater than 1,500 gpm, but due to the many businesses in the area the fire flow required is 3,500 gpm. An 8-inch water main on Boston Post Road is the sole supply for Old Country Road.

The hydraulic model was utilized to develop and analyze pipe improvement options to bring the deficient fire flow simulation locations into compliance. The following table summarizes the results of the evaluation and the resulting recommended pipe improvement options. All recommended fire flow improvements are presented on the map included in Appendix E.
### Table 4.4 - Additional Fire Flow Improvements

<table>
<thead>
<tr>
<th>Row Test No.</th>
<th>Model Fire Flow Locations</th>
<th>Required Fire Flow (gpm)</th>
<th>Available Fire Flow (gpm)*</th>
<th>Available Fire Flow with Improvement (gpm)</th>
<th>Required Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-16</td>
<td>Old Sudbury Rd at Harvey's Farm Ln</td>
<td>750</td>
<td>390</td>
<td>980</td>
<td>Option 1: Replace 4,750 feet of 8-inch CI water main with 8-inch DI water main on Old Sudbury Road and Rice Road from the Sudbury Town Office east to the end of the system.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Option 2: Replace 4,750 feet of 8-inch CI water main with 8-inch DI water main on Old Sudbury Road and Rice Road from the Sudbury Town Office east to the end of the system. &amp; Replace 650 feet of AC water main with 8-inch DI water main on Old Sudbury Road from Concord Road to the Sudbury Town Office.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Option 3 (Recommended): Clean and Line 4,750 feet of 8-inch CI water main on Old Sudbury Road and Rice Road from the Sudbury Town Office east to the end of the system.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Option 4: Install 1,400 feet of 8-inch DI water main behind private property using an existing easement from Fieldstone Farm Road to Candy Hill Lane. &amp; Replace 550 feet of 4-inch DI water main with 8-inch DI water main on Candy Hill Lane.</td>
</tr>
<tr>
<td>S-19</td>
<td>Old County Rd at Butch Auto</td>
<td>3,500</td>
<td>1,780</td>
<td>3,130</td>
<td>Option 1 (Recommended): Install 700 feet of 12-inch DI water main to connect 10-inch DI water main on Old Country Road to 8-inch DI water main on Old Country Road.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Option 2: Install 700 feet of 12-inch DI water main to connect 10-inch DI water main on Old Country Road to 8-inch DI water main on Old Country Road. &amp; Replace 1,300 of 8-inch AC water main with 12-inch DI water main on Boston Post Road from Landham Road to Goodman’s Hill Road.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Option 3: Install 700 feet of 12-inch DI water main to connect 10-inch DI water main on Old Country Road to 8-inch DI water main on Old Country Road. &amp; Replace 5,250 of 8-inch AC water main with 12-inch DI water main on Boston Post Road from Concord Road to Goodman’s Hill Road.</td>
</tr>
</tbody>
</table>
The fire flow improvement options for Simulation Test S-16 are shown in the figure below.

**Figure 4.4 - Fire Flow Improvement Options - S-16**

For S-16, Old Sudbury Road four options were presented in Table 4.4. Option 1 and Option 2 require water main to be removed and replaced in Old Sudbury Road. Option 4 requires installation of new water main behind private property through an existing easement. It will also require upsizing water main on Candy Hill Lane. Stantec recommends Option 3. This option
requires cleaning and lining of existing CI water main. Option 3 will bring the fire flow available at this location into compliance at the lowest cost.

For S-19, Old Country Road and Boston Post Road three options were also presented in Table 4.4. For this simulation fire flow requirements were met under maximum day conditions and with the wells offline only with Option 3. Option 2 and Option 3 both require a large section of water main on Boston Post Road to be replaced. Due to the heavy traffic and difficult construction on Boston Post Road, Stantec recommends Option 1. While this option does not bring the available fire flow into compliance, there is flow available to the area is above 3,000 gpm. If the wells are online the fire flow available is increased to 3,350 gpm. This improvement will also create a loop between Boston Post Road and Old Country Road, increasing water quality and system strength.

### 4.4 Undersized Mains

The Sudbury Water Distribution System is generally sized well for the system demand needs. There is limited 4-inch water main and less than 10% of the water mains are 6-inch or less. For new water main installations, 8-inch pipe is the minimum diameter accepted.

There is 280 feet of 4-inch cast iron pipe connecting the 8-inch cast iron water main in Old Sudbury Road to the 8-inch ductile iron water main that supplies The Peter Noyes School and the Town Offices. A closed valve on the 4-inch line forces supply to come from Concord Road. This eliminates supply from the old 8-inch cast iron pipe that Stantec has recommended replacing. We recommend eliminating the existing 4-inch water main and replacing it with a new 8-inch ductile iron water main. This improvement, coupled with the improvement in Old Sudbury road, would allow the District to open the water main and increase fire flow to the school without sacrificing water quality. The following table summarizes the recommended water main improvements and resulting increases to the available fire flow. This improvement should be constructed after or in coordination with the cleaning and lining of the 8-inch cast iron water main recommended in Old Sudbury Road.

<table>
<thead>
<tr>
<th>Improvement Locations</th>
<th>Available Fire Flow (gpm)*</th>
<th>Available Fire Flow with Improvement (gpm)</th>
<th>Recommended Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peter Noyes School/ Sudbury Town Offices</td>
<td>1,930</td>
<td>3,360</td>
<td>Replace 280 feet of 4-inch CI water main with 8-inch DI water main from 8-inch water main on Old Sudbury Road to the 8-inch water main at Peter Noyes School</td>
</tr>
</tbody>
</table>
4.5 UNLINED CAST IRON PIPE

The Sudbury Water District water system consists of mainly asbestos cement and ductile iron pipe. There are limited locations in the system that include unlined cast iron pipe. Although it makes up only about 2.2% of the entire water system, unlined cast iron pipe is prone to tuberculation which is likely to cause discolored water along with increasing headloss through the pipe segments.

The following table identifies recommendations to address the segments of unlined cast iron pipe in the Sudbury Water District’s distribution system.

**Table 4.6 - Unlined Cast Iron Pipe Improvements**

<table>
<thead>
<tr>
<th>Improvement Location</th>
<th>From</th>
<th>To</th>
<th>Diameter (inches)</th>
<th>Installation Year</th>
<th>Length (feet)</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Sudbury Road &amp; Rice Road</td>
<td>Sudbury Town Office</td>
<td>End of Water System</td>
<td>8</td>
<td>1970's</td>
<td>4,750</td>
<td>Pipe Recommendation presented in Table 4.4</td>
</tr>
<tr>
<td>Goodman's Hill Road</td>
<td>Concord Road</td>
<td>215 Goodman's Hill Road</td>
<td>12</td>
<td>1930's</td>
<td>3,100</td>
<td>Clean and Line 3,100 feet of 12-inch CI Pipe</td>
</tr>
<tr>
<td>Goodman's Hill Tank Supply</td>
<td>Goodman's Hill Road</td>
<td>Goodman's Hill Tank</td>
<td>12</td>
<td>1930's</td>
<td>750</td>
<td>Clean and Line 750 feet of 12-inch CI Pipe</td>
</tr>
<tr>
<td>Concord Road</td>
<td>Boston Post Road</td>
<td>Old Lancaster Road</td>
<td>12</td>
<td>1960's</td>
<td>4,400</td>
<td>Clean and Line 4,400 feet of 12-inch CI Pipe</td>
</tr>
</tbody>
</table>

The 8-inch cast iron pipe in Old Sudbury Road is in poor condition. It is most likely heavily tuberculated and acts as a major restriction in flow in the event of a fire. This pipe is a high priority improvement and recommendations have been made in Table 4.4.

The Goodman’s Hill Tank area includes some of the oldest pipe in the water distribution system. This area experiences high headloss during peak flow and fire flow condition. Stantec recommends addressing this location to increase water quality and also increase fire flow to the area surrounding Goodman’s Hill.

Concord Road includes a long segment of 12-inch cast iron pipe. This pipe was installed in the 1960’s and based on flow tests has a strong C-value, suggesting that it does not experience significant tuberculation. A 16-inch ductile iron water main was installed in Union Avenue in 2012 to help reduce headloss from the main Raymond Road Water Treatment Plant to supply the northern portion of The Water District Union Avenue runs parallel to the section of unlined cast iron pipe located in Concord Road, and consequently the section of cast iron pipe in Concord...
Adequacy of Distribution System Piping  
January 9, 2017

Road is not experiencing large flows or significant headloss. The pipe should be evaluated in the future as a possible pipe improvement to eliminate the unlined cast iron pipe or to clean and cement the water main to improve water quality in the area.

Any additional unlined cast iron pipe system should be considered for replacement or lining. By eliminating the remaining unlined cast iron pipe from the system, the District will see improved water quality, and increased capacity.

4.6 WATER DISTRIBUTION SYSTEM AREAS OF CONCERN

On October 19, 2016 Stantec met with Sudbury Water District staff to discuss areas of concern in the water distribution system. Stantec gathered feedback from the District and has prioritized areas for improvement below.

4.6.1 Asbestos Cement Mains

Asbestos Cement (AC) pipe was installed primarily in the 1940s, 1950s and 1960s in water distribution systems. The Sudbury Water District distribution system consists of 97.8 miles of AC pipe which is approximately 67% of the total water system. AC pipe has a typical lifespan of approximately 50-70 years, but the actual service life depends largely on pipe condition and installation environment.

Over time, AC pipe experiences gradual deterioration in the form of corrosion (i.e., external leaching due to groundwater). Leaching leads to a reduction in the cross-section of the pipe, which can lead to pipe softening and loss of structural integrity. Consequently, as the water distribution system ages, the number of leaks and pipe failures increases with time. The Water District has listed the following areas where deteriorating AC pipe has been identified.

- Hampshire Street Neighborhood: Hampshire Street, Canterbury Drive, Hemitage Street, English Road, Arrowhead Road
- Cedar Creek Road

The following Table 4.7 identifies recommendations to address the deteriorating areas of asbestos cement pipe in the Sudbury Water District’s distribution system.
Table 4.7 – Deteriorating Asbestos Cement Pipe Improvements

<table>
<thead>
<tr>
<th>Improvement Location</th>
<th>Diameter (inches)</th>
<th>Material</th>
<th>Installation Year</th>
<th>Length (feet)</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hampshire Street Neighborhood</td>
<td>10</td>
<td>Asbestos Cement</td>
<td>1967</td>
<td>1,730</td>
<td>Abandon in place 1,730 feet of 10-inch AC water main and install new 8-inch DI water main</td>
</tr>
<tr>
<td>Hampshire Street Neighborhood</td>
<td>8</td>
<td>Asbestos Cement</td>
<td>1968</td>
<td>2,620</td>
<td>Abandon in place 2,620 feet of 8-inch AC water main and install new 8-inch DI water main</td>
</tr>
<tr>
<td>Cedar Creek Road</td>
<td>8</td>
<td>Asbestos Cement</td>
<td>1968</td>
<td>2,280</td>
<td>Abandon in place 2,280 feet of 8-inch AC water main and install new 8-inch DI water main</td>
</tr>
</tbody>
</table>

While many other areas of the Water District have AC pipe, District staff have identified specific areas where AC should be replaced with new ductile iron water mains. In some cases these are areas where the AC pipe is believed to be beyond its design life. In other areas, District staff would like to upsize critical water main when replacing the AC water main. Increasing the hydraulic capacity at these locations will further improve fire flows and reliability in the system in the event of a major water main break. The following Table 4.8 identifies recommendations to address the aging asbestos cement pipe in areas of concern to District staff.

Table 4.8 – Additional Asbestos Cement Pipe Improvements

<table>
<thead>
<tr>
<th>Improvement Location</th>
<th>From</th>
<th>To</th>
<th>Diameter (inches)</th>
<th>Installation Year</th>
<th>Length (feet)</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peakham Road</td>
<td>Hudson Road</td>
<td>Old Lancaster Road</td>
<td>8</td>
<td>1960</td>
<td>3,210</td>
<td>Abandon in place 3,210 feet of 8-inch AC water main and install new 12-inch DI water main</td>
</tr>
<tr>
<td>Peakham Road</td>
<td>Old Lancaster Road</td>
<td>Pratt’s Mill Road</td>
<td>8</td>
<td>Unknown</td>
<td>2,230</td>
<td>Abandon in place 2,230 feet of 8-inch AC water main and install new 12-inch DI water main</td>
</tr>
<tr>
<td>Codjer Lane</td>
<td>Union Avenue</td>
<td>Concord Road</td>
<td>6</td>
<td>1956</td>
<td>1,590</td>
<td>Abandon in place 1,590 feet of 6-inch AC water main and install new 12-inch DI water main</td>
</tr>
<tr>
<td>Old Lancaster Road</td>
<td>Concord Road</td>
<td>Goodman’s Hill Road</td>
<td>8</td>
<td>1956</td>
<td>4,090</td>
<td>Abandon in place 4,090 feet of 8-inch AC water main and install new 8-inch DI water main</td>
</tr>
</tbody>
</table>
When reviewing these District recommended AC pipe replacement project, the Indian Ridge Pokonoket Avenue neighborhood should also be considered for replacement. This neighborhood is located to the south of the Old Lancaster Road recommended replacement. The water main in this area was installed in the 1950’s and a significant portion is 6-inch. Further investigation is recommended to determine if replacement is warranted when work occurs along Old Lancaster Road.
5.0 DISTRIBUTION SYSTEM OPERATION

Proper operation and maintenance of the District’s distribution system can maximize the protection of public health by maintaining reliable, high quality water for the customers. Proper disinfection procedures during the installation of new mains and when repairing leaks and breaks, replacement of deteriorated pipe, a tenacious cross-connection control program, a regular hydrant flushing program, a valve maintenance program, and a leak detection program are all key components to maintaining distribution system water quality.

5.1 PIPE MAINTENANCE

The Sudbury Water District currently performs unidirectional flushing of its distribution system every year during the spring and the fall. The District also operates valves during the flushing to increase the velocity in the pipes and to properly flush specific areas. The District performs leak detection every spring to identify any areas in the distribution system with significant loss of water.

5.2 STORAGE TANK MAINTENANCE

The 2.0 MG Willis Hill Storage Tank was inspected by Statewide Aquastore in May 2014. The tank was found to be in overall excellent condition. Statewide Aquastore recommended the following repairs.

- The exterior of the tank should be pressure washed and the graffiti removed.
- Lightning protection ground wire on the roof should be repaired.
- The non-skid walkway on the roof should be replaced.
- Periodic monitoring of the tank and the Cathodic Protection System.
- Adhere to standard inspection schedule.

In December 2015 the 350,000 gallon Goodman Hill Storage Tank was cleaned and sealed by Underwater Solutions. Accumulated precipitate was removed from the floor to improve the overall condition and integrity of the steel floor surfaces. Underwater Solutions also sealed a hole penetration in the roof dome.

Stantec recommends continuing a periodic inspection and cleaning program every 5 years. If these inspections indicate possible concerns or recommendations, the District should take the appropriate course of action. For planning purposes the tanks should be cleaned and painted every 20 years. For tank inspection reports refer to Appendix A.

5.3 WATER MAIN REPLACEMENT/REHABILITATION PROGRAM

The District does not currently have an annual water main replacement/rehabilitation program in place. Old unlined cast iron water mains that are appropriately sized but suffer from a buildup...
of tubercules are candidates for cleaning and lining. The majority of the water main in the
distribution system is asbestos cement pipe which would not be a candidate for cleaning in
lining. The findings of this report should be used to initiate a water replacement/rehabilitation
program. Stantec has identified water main improvements for the Sudbury Water District water
system. These improvements include fire flow improvements, replacement of small undersized
mains, replacement of old unlined cast iron pipe segments, and areas of concern identified by
the Water District. These improvements can be separated and prioritized into separate
construction contracts in order to appropriately fund the improvements over a number of years.
Work should also be prioritized based on water quality complaints and coordination with other
infrastructure improvements such as other utility and repaving projects. Recommended
improvements are presented in Table 5.1.

Since the majority of the water system is AC pipe, consideration should be given to the
evaluation of the condition of this AC pipe. Condition assessment for AC pipe measures the
pipe wall thickness through acoustical methods and compares existing wall thickness to original
wall thickness to identify remaining life. It is not feasible to evaluate all the AC pipe in the entire
water system. Instead, Stantec recommends that a one to two-mile pilot area be investigated
that includes both high groundwater levels and dry conditions. Based on the pilot area, data
collected can be extrapolated to other areas of the water system where age and installation
conditions are similar. This will assist in prioritizing the replacement of AC pipe within the water
distribution system over time. Break and leak data should also be documented moving forward
to help prioritize future improvements.
## Table 5.1 - Proposed Water Main Improvements

<table>
<thead>
<tr>
<th>IMPROVEMENTS</th>
<th>Total Length</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fire Flow Improvements</strong></td>
<td></td>
</tr>
<tr>
<td>• Clean and Line 4,750 feet of 8-inch CI water main on Old Sudbury Road and Rice Road from the Sudbury Town Office east to the end of the water system</td>
<td>4,750 feet</td>
</tr>
<tr>
<td>• Install 700 feet of 12-inch ductile iron water main to connect 10-inch ductile iron water main on Old Country Road to 8-inch ductile iron water main on Old Country Road.</td>
<td>700 feet</td>
</tr>
<tr>
<td><strong>Undersized Mains</strong></td>
<td></td>
</tr>
<tr>
<td>• Replace 280 feet of 4-inch cast iron water main with 8-inch ductile iron water main from 8-inch water main on Old Sudbury Road to the 8-inch ductile iron water main at Peter Noyes School</td>
<td>280 feet</td>
</tr>
<tr>
<td><strong>Unlined Cast Iron Pipe</strong></td>
<td></td>
</tr>
<tr>
<td>• Clean and Line 3,100 feet of 12-inch cast iron pipe on Goodman’s Hill Road from Concord Road to 215 Goodman’s Hill Road</td>
<td>3,100 feet</td>
</tr>
<tr>
<td>• Clean and Line 750 feet of 12-inch cast iron pipe from Goodman’s Hill Tank to Goodman’s Hill Road</td>
<td>750 feet</td>
</tr>
<tr>
<td>• Clean and Line 4,400 feet of 12-inch cast iron pipe on Concord Road from Boston Post Road to Old Lancaster Road</td>
<td>4,400 feet</td>
</tr>
<tr>
<td><strong>Water District Areas of Concern</strong></td>
<td></td>
</tr>
<tr>
<td>• Abandon in place 1,730 feet of 10-inch AC water main and install new 8-inch DI water main in the Hampshire Street Neighborhood</td>
<td>1,730 feet</td>
</tr>
<tr>
<td>• Abandon in place 2,620 feet of 8-inch AC water main and install new 8-inch DI water main in the Hampshire Street Neighborhood</td>
<td>2,620 feet</td>
</tr>
<tr>
<td>• Abandon in place 2,280 feet of 8-inch AC water main and install new 8-inch DI water main on Cedar Creek Road</td>
<td>2,280 feet</td>
</tr>
<tr>
<td>• Abandon in place 3,210 feet of 8-inch AC water main and install new 12-inch DI water main on Peakham Road</td>
<td>3,210 feet</td>
</tr>
<tr>
<td>• Abandon in place 2,230 feet of 8-inch AC water main and install new 12-inch DI water main Peakham Road</td>
<td>2,230 feet</td>
</tr>
<tr>
<td>• Abandon in place 1,590 feet of 6-inch AC water main and install new 12-inch DI water main on Codjer Lane</td>
<td>1,590 feet</td>
</tr>
<tr>
<td>• Abandon in place 4,090 feet of 8-inch AC water main and install new 8-inch DI water main on Old Lancaster Road</td>
<td>4,090 feet</td>
</tr>
</tbody>
</table>
6.0 RECOMMENDATIONS

Generally, Sudbury Water District’s water distribution system is strong and well looped. There are several localized areas where fire flows are deficient. Even with a total of four water storage tanks, the existing distribution system does not have adequate usable storage due to the elevations of some houses near the Bigelow and Goodman Hill Tanks. By solving these pressure problems locally, the existing storage capacity is sufficient. Some distribution system improvements are required in order to meet localized fire flows, replace undersized mains, replace unlined cast iron pipe, and replace pipe in areas of concern identified by the Water District. The distribution system recommendations are presented in the following Table 6.1 and are show on the plan in Appendix E.

An Engineer’s opinion of probable costs has been developed in the Table 6.1 below. These construction costs do not include legal fees, land and easement costs or other administrative costs, but they do include an allowance for engineering and contingencies, assuming the work will be done in the 2016 construction season. Estimated costs should be verified with the Engineer prior to allocation of funds for the selected project(s) for each fiscal year. In some cases, preliminary engineering studies may be required to identify the extent of work and associated costs.

<table>
<thead>
<tr>
<th>IMPROVEMENTS</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fire Flow Improvements</strong></td>
<td></td>
</tr>
<tr>
<td>• Clean and Line 4,750 feet of 8-inch CI water main on Old Sudbury Road and Rice Road from the Sudbury Town Office east to the end of the water system</td>
<td>$523,000</td>
</tr>
<tr>
<td>• Install 700 feet of 12-inch ductile iron water main to connect 10-inch ductile iron water main on Old Country Road to 8-inch ductile iron water main on Old Country Road.</td>
<td>$119,000</td>
</tr>
<tr>
<td><strong>Undersized Mains</strong></td>
<td></td>
</tr>
<tr>
<td>• Replace 280 feet of 4-inch cast iron water main with 8-inch ductile iron water main from 8-inch water main on Old Sudbury Road to the 8-inch ductile iron water main at Peter Noyes School</td>
<td>$38,000</td>
</tr>
<tr>
<td><strong>Unlined Cast Iron Pipe</strong></td>
<td></td>
</tr>
<tr>
<td>• Clean and Line 3,100 feet of 12-inch cast iron pipe on Goodman’s Hill Road from Concord Road to 215 Goodman’s Hill Road</td>
<td>$434,000</td>
</tr>
<tr>
<td>• Clean and Line 750 feet of 12-inch cast iron pipe from Goodman’s Hill Tank to Goodman’s Hill Road</td>
<td>$105,000</td>
</tr>
<tr>
<td>• Clean and Line 4,400 feet of 12-inch cast iron pipe on Concord Road from Boston Post Road to Old Lancaster Road</td>
<td>$616,000</td>
</tr>
</tbody>
</table>
Water District Areas of Concern

- Abandon in place 1,730 feet of 10-inch AC water main and install new 8-inch DI water main in the Hampshire Street Neighborhood $260,000
- Abandon in place 2,620 feet of 8-inch AC water main and install new 8-inch DI water main in the Hampshire Street Neighborhood $393,000
- Abandon in place 2,280 feet of 8-inch AC water main and install new 8-inch DI water main on Cedar Creek Road $342,000
- Abandon in place 3,210 feet of 8-inch AC water main and install new 12-inch DI water main on Peakham Road $610,000
- Abandon in place 2,230 feet of 8-inch AC water main and install new 12-inch DI water main on Peakham Road $424,000
- Abandon in place 1,590 feet of 6-inch AC water main and install new 12-inch DI water main on Codjer Lane $303,000
- Abandon in place 4,090 feet of 8-inch AC water main and install new 8-inch DI water main on Old Lancaster Road $614,000

Operation and Maintenance Recommendations

- Annual Flushing -
- Leak Detection $10,000
- AC Pipe Condition Assessment 1-2 Mile Pilot Area $40,000-$65,000
Appendix A

A.1 WATER DISTRIBUTION MAP
Appendix B

B.1 HYDRANT FLOW TEST MAP
Appendix C

C.1 ISO HYDRANT FLOW TEST RESULTS
## HYDRANT FLOW DATA SUMMARY

**City:** Sudbury  
**County:** Massachusetts (Middlesex)  
**State:** Massachusetts  
**Witnessed by:** Insurance Services Office  
**Date:** Nov 19, 2014

<table>
<thead>
<tr>
<th>TEST NO.</th>
<th>TYPE DIST.*</th>
<th>TEST LOCATION</th>
<th>SERVICE</th>
<th>FLOW - GPM O=2983(C(d^d))</th>
<th>PRESSURE PSI</th>
<th>FLOW - AT 20 PSI</th>
<th>REMARKS***</th>
<th>MODEL TYPE</th>
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<tbody>
<tr>
<td>1</td>
<td></td>
<td>Great Road &amp; North Road</td>
<td>Sudbury Water District, Main</td>
<td>1300 0 0 1300</td>
<td>114 93</td>
<td>2250 2900</td>
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<td></td>
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<tr>
<td>10</td>
<td></td>
<td>Boston Post Rd &amp; Uplook Dr</td>
<td>Sudbury Water District, Main</td>
<td>1400 0 0 1400</td>
<td>136 120</td>
<td>2500 4100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>French Rd &amp; Red Horse Path</td>
<td>Sudbury Water District, Main</td>
<td>1380 0 0 1380</td>
<td>133 118</td>
<td>500 4100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>Pratt Mill Rd &amp; Melean Dr</td>
<td>Sudbury Water District, Main</td>
<td>1400 0 0 1400</td>
<td>130 120</td>
<td>4000 5100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12A</td>
<td></td>
<td>Pratt Mill Rd &amp; Melean Dr</td>
<td>Sudbury Water District, Main</td>
<td>1400 0 0 1400</td>
<td>130 120</td>
<td>500 5100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>Dutton Rd &amp; Poplar</td>
<td>Sudbury Water District, Main</td>
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<td>132 116</td>
<td>500 4000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>Fairbank Rd &amp; Butler</td>
<td>Sudbury Water District, Main</td>
<td>1450 0 0 1450</td>
<td>128 120</td>
<td>4500 5900</td>
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<td>1450 0 0 1450</td>
<td>128 120</td>
<td>500 5900</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Haynes Rd &amp; Hadley</td>
<td>Sudbury Water District, Main</td>
<td>1400 0 0 1400</td>
<td>124 108</td>
<td>2500 3800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Concord Road &amp; Faj Trail</td>
<td>Sudbury Water District, Main</td>
<td>1350 0 0 1350</td>
<td>124 109</td>
<td>500 3800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Morse Road</td>
<td>Sudbury Water District, Main</td>
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<td>144 124</td>
<td>500 3900</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Lincoln Rd &amp; Concord</td>
<td>Sudbury Water District, Main</td>
<td>1240 0 0 1240</td>
<td>135 99</td>
<td>2000 2300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Old Sudbury &amp; Concord</td>
<td>Sudbury Water District, Main</td>
<td>810 0 0 810</td>
<td>113 100</td>
<td>3500 2300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Boston Post Rd &amp; Old Country</td>
<td>Sudbury Water District, Main</td>
<td>1400 0 0 1400</td>
<td>155 124</td>
<td>3500 3100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Landham Rd &amp; Pelham Island</td>
<td>Sudbury Water District, Main</td>
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<td>148 126</td>
<td>3000 4100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Boston Post Rd &amp; Union Ave</td>
<td>Sudbury Water District, Main</td>
<td>1640 0 0 1640</td>
<td>154 134</td>
<td>3500 4600</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**THE ABOVE LISTED NEEDED FIRE FLOWS ARE FOR PROPERTY INSURANCE PREMIUM CALCULATIONS ONLY AND ARE NOT INTENDED TO PREDICT THE MAXIMUM AMOUNT OF WATER REQUIRED FOR A LARGE SCALE FIRE CONDITION.**

**THE AVAILABLE FLOWS ONLY INDICATE THE CONDITIONS THAT EXISTED AT THE TIME AND AT THE LOCATION WHERE TESTS WERE WITNESSSED.**

*Comm = Commercial; Res = Residential.*

**Needed is the rate of flow for a specific duration for a full credit condition. Needed Fire Flows greater than 3,500 gpm are not considered in determining the classification of the city when using the Fire Suppression Rating Schedule.**

*** (A)-Limited by available hydrants to gpm shown. Available facilities limit flow to gpm shown plus consumption for the needed duration of (B)-2 hours, (C)-3 hours or (D)-4 hours.
Appendix D

D.1  TANK INSPECTION REPORTS
May 28, 2014

Sudbury Water District
PO Box 111
Sudbury, MA 01776

Attention: Al Renzi

Subject: Aquastore Tank Inspection Report
   Model 9142  MIP 8061445

Dear Al,

On May 21, 2014, an inspection of the above referenced tank was performed with the use of a remote observation vehicle. We found the tank to be in very good condition.

On the tank interior, both the glass coating and sealer appeared to be in good condition. On the tank exterior, the glass coating and sealer is in good condition.

Please find enclosed a copy of the written report and a DVD video of the inspection. It is our opinion that overall the tank is in very good condition throughout.

If I can be of any additional assistance, or if you have any questions in the future, please do not hesitate to contact me.

Respectfully,
STATEWIDE AQUASTORE, INC.

Charlie Gage
Construction Manager

*Service provided by Factory Trained Certified Builders and Genuine Aquastore Parts are used.*
Sudbury, MA
Aquastore Water Storage Tank Inspection
Wet Inspection – 5/21/2014
Model 9142, 2,060,000 Gallons, MIP - 8061445
Sudbury, MA
Aquastore Water Storage Tank Inspection
Wet Inspection – 5/21/2014
Model 9142, 2,060,000 Gallons, MIP - 8061445

Scope:

On 5/21/2014, Statewide Aquastore, Inc conducted an interior and exterior inspection of the 2,060,000 gallon Aquastore® water storage tank noted above. This inspection is to provide information regarding the overall condition of the tank. The tank has been in service for approximately 7 years. It was installed in 2006 and put in service in 2/2007.

Exterior Inspection:

The exterior of the tank, and all appurtenances were inspected. This inspection included the sidewall sheets with glass coating, web truss rings, visible part of the tank foundation, area immediately adjacent to the tank (grade elevations, drainage, fencing, trees, etc.), bottom manway, ladder, safety cage, manway platform, overflow, roof, roof hatch, vent (on the roof), walkway, safety decals, nametag and sealant fillets.

EXTERIOR SIDEWALL SHEETS

Sealant:

- Manus sealant was used in the construction of this tank. Little to no sealant wear is evident.

Sidewall Sheets:

- Sidewall sheets, sheet edges, fillets, joints, hardware, etc. are in very good condition.
- Some algae growth was visible on the side walls. This is not a structural concern, but should be cleaned off.

Sidewall Fasteners:

- Protective caps utilized on the tank are in excellent condition.

Vertical Expansion:

- No vertical seam expansion is visible and appears to be non-existent.

Vandalism & Safety Decals:

- Some graffiti was present on the side walls.
- All safety decals and nametags are in their proper places and are intact.
Other Comments: Graffiti was seen on a few of the panels near the manway and ladder system.

WEB-TRUSSES

- The tank was constructed with L, three inch galvanized web-truss rings securely bolted in place. These appear to be in excellent condition.

FOUNDATION

Curb:

- The concrete curb foundation was inspected throughout the circumference and found to be in excellent condition.
- Minor radial cracking is present in the curb area. These cracks pose no structural concern and no repairs are necessary.

Perimeter Seal:

- The perimeter seal between the side-wall and the concrete curb is in excellent condition.

Drainage:

- Drainage around the tank is good.

SIDE ACCESS MANWAY (HEAVY DUTY COVER/DAVIT ARM ASSEMBLY)

- The tank was constructed with one, 24" bottom manway.
- The manway is in excellent condition with all fasteners in place and no signs of leakage present.
- The manway davit arm is secure and in good condition.
- The reinforcing plate is in excellent condition.

LADDER & CAGE

- The entire ladder, step off platform, safety cage, etc. is in excellent condition and securely bolted to the tank.
- A ladder blocking device is present and secured with a Water Department padlock, or a SWA padlock.
- The ladder starts at the top of the first ring.

ROOF, VENT, TOP MANWAY, SAFETY CAGE (CATWALK)

Roof:

- The entire roof and appurtenances were inspected and overall are in excellent condition.

Page 3 of 7
Roof, Vent, Manway, Overflow Penetration:

- The roof and appurtenances as viewed from the inside by optical means are found to be in very good condition.
- The roof panel skins and beam network appear to be in good condition.
- The vent screening on the 20” diameter vent is clean and clear.
- The roof manway is in good condition.
- The overflow is clean and clear.

Cathodic Protection System:

- A passive (Zinc) Cathodic Protection System is installed in the tank.
- The anodes appear to be in good condition.
- The original system consisted of 12 (Zinc) anodes, 12 primary and 0 secondary.

Other Comments: The CP System was tested during this inspection and found to be providing adequate protection to the wetted surfaces of the tank.

Mixer, Ancillary Equipment:

- The Tide Flex system is in excellent condition.

Conclusion:

- It is the opinion of SWA that, at the time of this inspection, this tank is in excellent condition throughout.
- It is the opinion of SWA that the following repairs should be made.
- The exterior of the tank should be pressure washed and the graffiti removed.
- Lightening protection ground wire on the roof should be repaired.
- The non-skid walkway on the roof should be replaced.
- We recommend, periodic monitoring of the tank and the Cathodic Protection System.
- It is our conclusion that this tank is performing well within the manufacturers parameters.
- We recommend this tank adhere to a standard inspection schedule.
- We recommend re-inspection of this tank in five years in accordance with recommendations from AWWA Standard D-103.

Notes:

- Present at this inspection were Justin Fitch of Statewide Aquastore Inc and John McConnon from Sudbury, MA.

- Security - It is the owners’ responsibility to close the tank back up to his/her requirements, including sanitizing, and to secure the tank and the area.
• A quote will be provided to the Sudbury MA Water Dept. for the above mentioned repairs upon request.

Water Properties:
• Conductivity 499 uS/cm
• TDS 270 mg/L

Other Comments: The tank was found to be in overall excellent condition. The exterior sidewall sheets have a noticeable amount of algae and pollen accumulated on them, as well as, graffiti. The sidewall sheets should be cleaned with a pressure washer. The non-skid walkway on the roof has become detached in many places and the lightening protection ground wire has become severed in two spots. Both of these issues should be addressed. A manlift maybe needed to repair the lightening protection. There was roughly ¼ inch to ½ inch of sediment on the floor. It was not possible to inspect the glass floor due to this.
CLEANING (SEDIMENT REMOVAL) AND SEALING OF ROOF PENETRATIONS OF THE 350,000-GALLON RIVETED STEEL WATER STORAGE TANK

SUDBURY WATER DISTRICT
SUDBURY, MASSACHUSETTS

DECEMBER 7, 2015
January 29, 2016

Ms. Rebecca McEnroe
Sudbury Water District
199 Raymond Road
Sudbury, MA 01776

Dear Rebecca,

I would like to thank you for your continued consideration in utilizing Underwater Solutions Inc. for the cleaning and sealing of roof penetrations of the 350,000-Gallon riveted steel water storage tank.

Please find enclosed the report of our findings accompanied by corresponding photographs, as well as a copy of the invoice and agreement that was previously mailed to your attention.

If you should have any questions, please contact me.

Again, thank you for your continued consideration and we look forward to working with you again in the future.

Sincerely,

UNDERWATER SOLUTIONS INC.

Kim L. Peets
Office Manager

Enclosures
UNDERWATER SOLUTIONS, INC.

Commercial Diving Services
Industrial • Commercial • Municipal

PO Box 208 • Mattapoisett, MA 02739 • 508-758-6126

System Billing

Sudbury Water District
199 Raymond Road
Sudbury, MA 01776

Attn:
Ms. Rebecca McEnroe

System Location

Sudbury Water District

<table>
<thead>
<tr>
<th>Order Date</th>
<th>Purchase Order</th>
<th>Service Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/28/2015</td>
<td>Per Agreement</td>
<td>12/7/2015</td>
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</tbody>
</table>

Description of Services Performed

Cleaning and Sealing of Roof Penetrations of the 350,000-Gallon Riveted Steel Water Storage Tank

Price

$6,990.00

Work Performed:
December 7, 2015

Thank You for your Business!

Interest of 1 \(^{1/2}\)\% per month will be charged on balances not paid at maturity

Please Pay This Amount

$6,990.00

COPY PAID

12-26-16
AGREEMENT

BETWEEN UNDERWATER SOLUTIONS INC. AND SUDBURY WATER DISTRICT, MA
FOR THE INTERIOR CLEANING (SEDIMENT REMOVAL) AND SEALING OF ROOF PENETRATIONS
OF THE 350,000-GALLON RIVETED STEEL WATER STORAGE TANK AS FOLLOWS:

The Sudbury Water District, Massachusetts agrees to have Underwater Solutions Inc. perform the above
mentioned work as per the conditions/terms and costs stated on the proposal dated October 27, 2015 (copy attached).

PERSONNEL:

GEAR:

Divers / Tenders
Complete Sanitized Inspection/Cleaning Dive Station
(All gear sanitized and utilized only in potable water.)
3’ Pump
3” Suction Hose
3’ Discharge Hose
25 CFM Compressor
400’ Dive Rig
Ladders
Bailout Bottle
Emergency Air
Volume Tank and Filter
Communications Box
200 ppm Chlorine Solution
Camera
Manifold
Dry Suit
SuperLite Helmet
Miscellaneous Tools

SUBMITTALS:

An outline of our findings and corresponding photographs will be submitted.

COST:

While mobilized in your area, Fall 2015:

Cleaning (sediment removal) up to 4” of sediment and sealing of roof penetrations: $6,990.00*

Additional hourly rate for sediment exceeding 4”: $495/hr

PAYMENT TERMS:

Payable Upon Receipt

IN ACCEPTANCE OF AFORESAID AGREEMENT:

UNDERWATER SOLUTIONS INC.
Signature of Authorized Representative

Director of Operations October 27, 2015

Supervisor

SUDBURY WATER DISTRICT, MASSACHUSETTS
Signature of Authorized Representative

 matériaux

Note: The term "one mobilization" refers to allowing Underwater Solutions Inc. access to all site(s) at all times throughout the project. Should operations not allow for complete access to all site(s) throughout the entire project, an additional charge shall be incurred.
CLEANING (SEDIMENT REMOVAL) AND SEALING OF ROOF PENETRATIONS OF THE 350,000-GALLON RIVETED STEEL WATER STORAGE TANK

SUDBURY WATER DISTRICT
SUDBURY, MASSACHUSETTS

DECEMBER 7, 2015

SCOPE:

On December 7, 2015, Underwater Solutions Inc. removed the accumulated precipitate from the floor of the 350,000-gallon riveted steel potable water storage tank to conclude the overall condition and integrity of the riveted steel floor surfaces. Underwater Solutions Inc. personnel also sealed the rigging hole penetrations within the roof dome.

Sediment Accumulations

Upon entering the tank, a uniform layer of accumulated precipitate, ranging from 1-1/2” to 2” in depth was found throughout the floor.

Floor

After completely removing the accumulated precipitate from the floor of this tank. The steel floor panels and associated rivets were inspected and were found appearing sound and free of obvious fatigue (pitting) of the steel panels or deterioration of the rivets.

The protective coating applied to these steel floor panels and rivets was found having good adhesion value, providing adequate protection for these steel surfaces.

Moderate staining exists throughout the entire floor due to the accumulation of precipitate.
CLEANING (SEDIMENT REMOVAL) AND SEALING OF ROOF PENETRATIONS OF
THE 350,000-GALLON RIVETED STEEL WATER STORAGE TANK
SUDBURY WATER DISTRICT
SUDBURY, MASSACHUSETTS
DECEMBER 7, 2015
PAGE 2

After removing the accumulated precipitate from the floor of the tank, personnel from
Underwater Solutions Inc. found a total of twenty-four, 4” by 4” rigging hole
penetrations within the roof. Eighteen of these rigging hole penetrations were found
covered with a 6” by 6” steel cover plates, while six of these penetrations were found
without cover plates and open, allowing access to the interior of the tank.

Underwater Solutions Inc. fabricated six new 6” by 6” cover plates utilizing, 12 gauge
galvanized steel with aluminum backing, and secured with galvanized screws with rubber
gaskets.

After installing the six new cover plates over the open rigging hole penetrations an
elastomeric sealant was applied throughout the perimeter of each newly installed cover plate, as well as each of the eighteen existing cover plates in an effort to prevent
rainwater and other contaminates from entering the interior of the tank.

As always, we recommend re-inspection and cleaning of all water storage facilities in
accordance with state and federal mandates, A.W.W.A. standards, and be completed by
an experienced and authorized inspection corporation.

[Signature]

UNDERWATER SOLUTIONS INC.
Christopher A. Cole, Project Manager

This report, the conclusions, recommendations and comments prepared by Underwater
Solutions Inc. are based upon spot examination from readily accessible parts of the tank.
Should latent defects or conditions which vary significantly from those described in the
report be discovered at a later date, these should be brought to the attention of a
qualified individual at that time. These comments and recommendations should be
viewed as information to be used by the Owner in determining the proper course of
action and not to replace a complete set of specifications. All repairs should be done in
accordance with A.W.W.A. and/or other applicable standards.
Appendix E

E.1 DISTRIBUTION SYSTEM RECOMMENDATIONS
APPENDIX E - DISTRIBUTION RECOMMENDATIONS
SUDbury WATER DISTRICT
TOWN OF SUDbury
MASSACHUSETTS

Legend
- Water Treatment Plant
- Pump Station
- Storage Tank
- Diameter (Inches)
  - 4
  - 6
  - 8
  - 10
  - 12
  - 16
  - UNK
- Pipe Improvements
  - Clean and Line
  - Abandon & Install
  - Install
  - Replace

Replace
10''-PVC

8''-AC

APPENDIX E - DISTRIBUTION RECOMMENDATIONS
FIRECUT LN
8''-AC

BEECHWOOD AVE
8''-AC

FAIRBANK RD
8''-PVC

GUGGEEY

WATER SYSTEM HYDRAULIC MODEL REPORT
APPENDIX E
DISTRIBUTION RECOMMENDATIONS

Stantec

Date: 1/2/2017