Draft Report

WATER MODELING AND HYDRAULIC EVALUATION

MIDDLEBURY, VERMONT

October 19, 2018

Submitted to:
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Infrastructure Committee
Town of Middlebury
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SECTION 1
EXISTING CONDITIONS
WATER MODELING AND HYDRAULIC EVALUATION REPORT
MIDDLEBURY, VERMONT

General System Description

The Middlebury Water Department Water System (WSID 5004) is supplied by three wells located about 3 miles east of the Town center, off Case Street. Water storage is provided by Chipman Reservoir, a two-cell 1.5 million gallon (mg) tank on Chipman Hill. The system operates as a single pressure zone. The location of the water system components, including the wells, the storage tank and water mains is shown in Figure 1. A full size scale basemap is included in the Appendices.

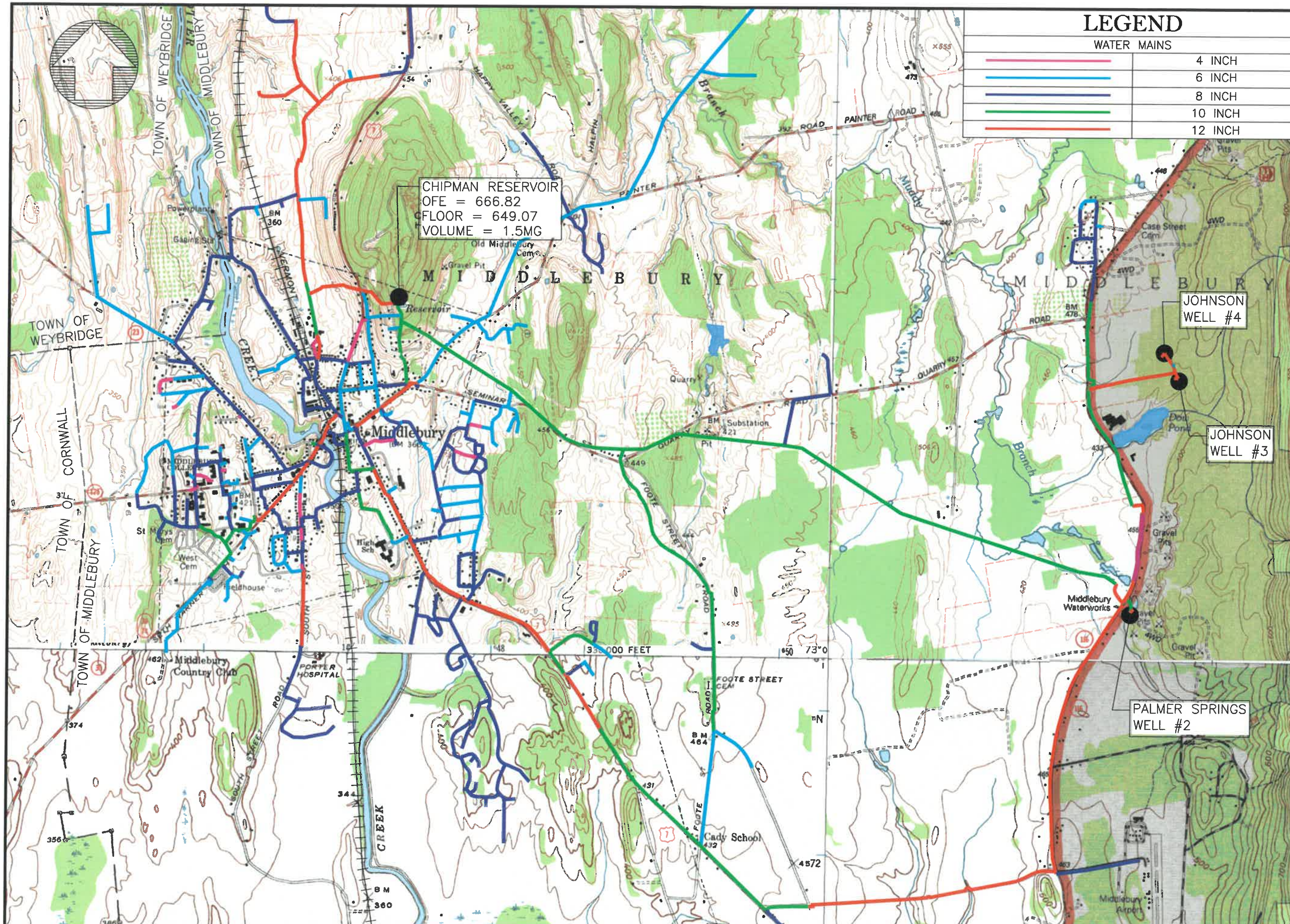
The system serves a year-round population of approximately 5,800 with 2,200 service connections, as reported in the 2017 Sanitary Survey. Water customers are a mixture of residential, commercial and industrial types. The system's largest user is Middlebury College, served through four interconnection points.

Based on a review of the 2018 metered water usage to date (January 1, 2018 through mid-October 2018) the water supplied to the college represents 18% of the total metered flows for this time period. The college buildings and facilities are individually metered with a total of 156 accounts. The college owns and maintains the distribution system on campus but is not a separate water system.

The water system was originally constructed in 1891 with 7.5 miles of distribution mains, according to the *Manual of American Water-Works Volume 4* published in 1897. Since the original construction, the major system modifications that are currently in service include construction of the Chipman Reservoir in 1978 and construction of the three wells (Wells 2, 3, 4) at individual times.

The Chipman Reservoir is a cast-in-place concrete structure with two 78'-3" x 77'-8" cells that have a depth of 17.25' to the overflow, which is at elevation 666.84'. The tank does not have an altitude valve.

Well 2 at Palmer Springs, developed in 1978, is the primary source of supply with an original design pumping rate of 1,500 gpm and an authorized rate of 1,550 gpm. The well is controlled to turn on when the Chipman Reservoir level drops to 14 ft and turn off at a level of 16 ft. At the 16 ft level, either Well 3 or Well 4 (the Johnson Wells) will turn on and run until additional supply from Well 2 is required to refill the Chipman Reservoir to above the 14 ft level.



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Project Mgr.	TPK
Design	N/A
Drawn	MCB
Checked by	NRJ
Date	10/3/2018
Scale	1"=2000'
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WATER SYSTEM FACILITIES LOCATION MAP

MIDDLEBURY, VERMONT

FIG 1

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Wells 3 and 4 are operated on an alternating basis. Well 3, developed in 1985, supplies about 400 gpm. Well 4, developed in 1997, supplies 450 gpm. The capacity of Well 4 is substantially less than the 800 gpm safe yield for this source. This well has issues with introducing sand to the water system and reported pump cavitation at high flows.

A new Permit to Operate was issued on April 17, 2013, with no expiration date, as is the policy of the Drinking Water and Groundwater Protection Division. The most recent Sanitary Survey was conducted by the Vermont Drinking Water and Groundwater Protection Division staff on September 29, 2017. The survey identified the requirements to continuously monitor disinfectant residual, repair or replace the Chipman Reservoir roof and install security measures for the tank. The Town has addressed these three items.

The Sanitary Survey also identified that Chipman Reservoir provides inadequate storage volume. This water modeling report addresses the requirement, outlined by the Drinking Water and Groundwater Protection Division, to evaluate and plan for providing additional storage capacity, as well as discuss fire flow capabilities and future average day demands.

System Demands

Total water supplied to the Middlebury Water System is measured by flow meters at the three well houses and monitored by the SCADA system. Water Department staff read and manually record the master meters' values daily. If there is any variation in the time of day the meter reading is recorded, the daily values are not representative of supply over a 24-hour period. The source supplies water to meet system demands and maintain storage volume in the Chipman Reservoir.

Water consumption varies from hour to hour and from day to day throughout the year. Average daily demand is the average of the total amount of water used each day during a one-year period. The maximum day demand is defined as the highest total amount of water used during any twenty-four hour period. Typically, the previous three years of data is reviewed to identify the maximum day demand value.

The water supply data for 2007 to 2017 was reviewed to determine water system demands. This data is plotted in Figure 2. Table 1 summarizes the Middlebury Water System average day demands for 2015-2017.

FIGURE 2
WATER SYSTEM HISTORICAL DEMAND
MIDDLEBURY, VERMONT

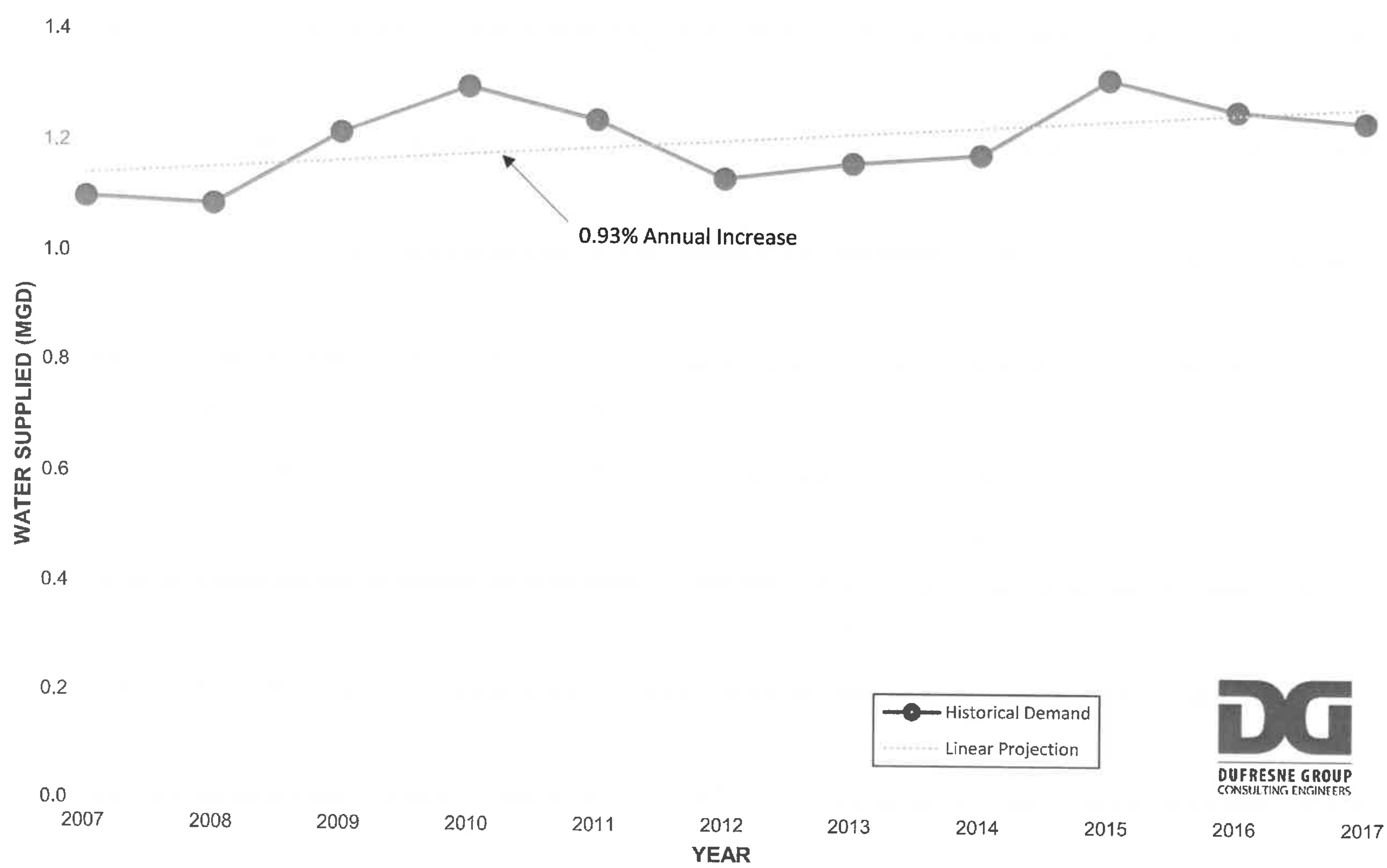


TABLE 1
AVERAGE DAILY DEMAND

Year	Average Day Demand
2015	1.32 mgd
2016	1.26 mgd
2017	1.24 mgd
Average	1.27 mgd

Notes:
1. The average day demand is estimated based on water supplied, measured by the master water meters at the well houses and totalized. Water supplied includes consumption and water loss.

Average Day (ADD), Maximum Day (MDD) and Peak Hour Demands (PHD) are listed in Table 2. The peaking factors reported in Table 2 are the ratios of the maximum day and peak hour demands to the average day demand. These values commonly range from 1.5-3 for the MDD/ADD ratio and from 2.5-5 for the PHD/ADD ratio, according to the *Handbook of Public Water Systems*. The values for Middlebury are at the low end of the range, which indicates that leakage may be significant, as leakage tends to dampen the peaking factors.

TABLE 2
CURRENT SYSTEM DEMANDS

Period	Demand	Peaking Factor to Average Day
Average Day	1.24 mgd	
Maximum Day	2.09 mgd	1.69
Peak Hour	2,000 gpm	2.3

Notes:
1. Master meter records for 2015-2017 were reviewed to determine the maximum day demand (MDD), which is reported as the highest MDD value during the three year period.
2. The average day demand is the value for calendar year 2017.
3. The maximum day demands were 2.09, 1.88, 2.00 mgd during 2015, 2016 and 2017 respectively.
4. The peak hour flow was estimated by a review of well production and tank level fluctuations during a maximum day. For the day analyzed, well production was 1,700 gpm average.

An analysis of large water users was conducted during the preparation of a computer model for the Middlebury Water System. The ten accounts with the highest historical consumption were identified and the average day demand for the computer model nodes at the account locations was assigned from metered usage provided by the Town. These ten highest use accounts have a total average daily consumption of 314,000 gpd or about 25% of the system metered demand.

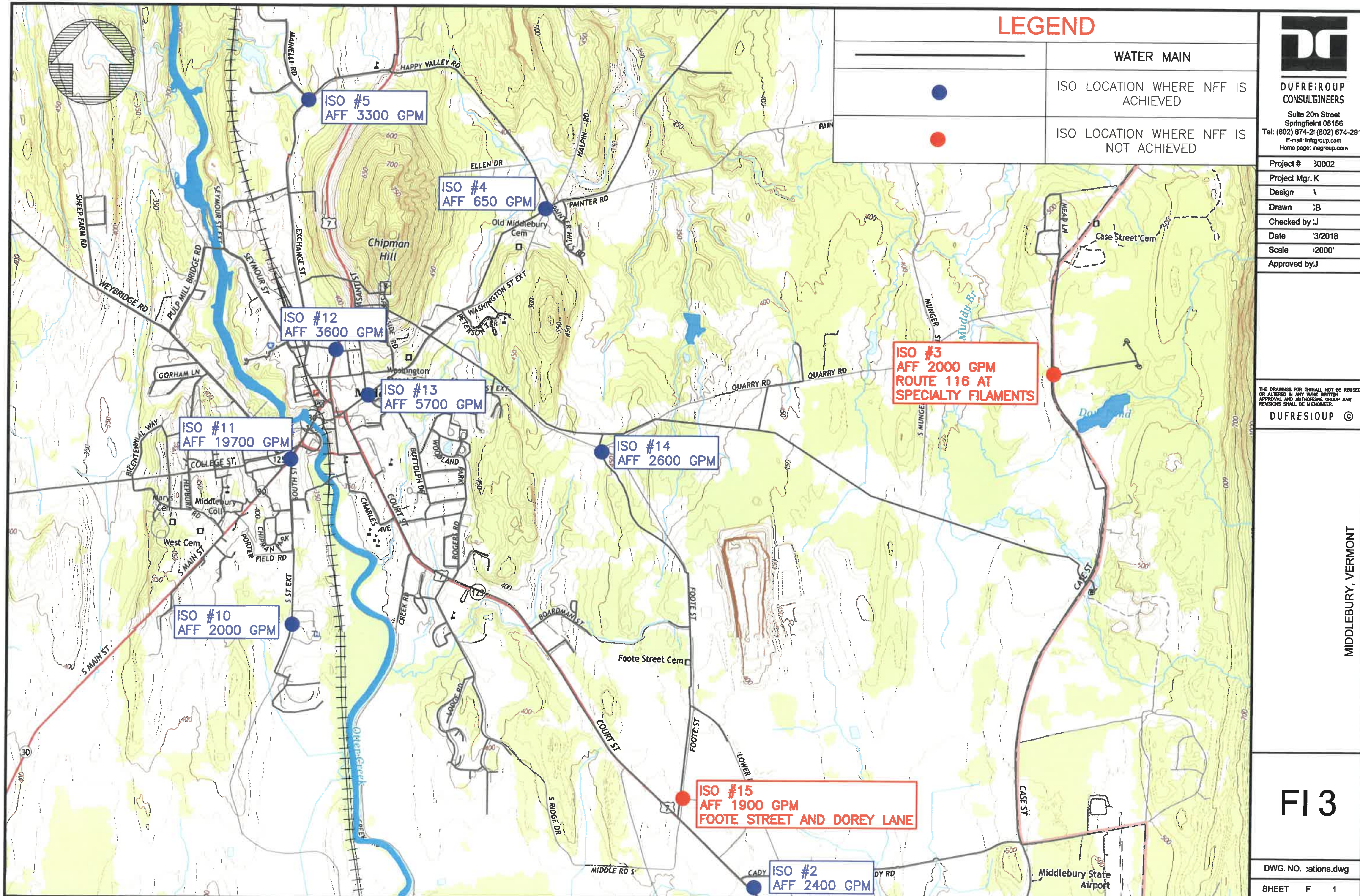
System Pressures and Surges

Water pressure for the distribution system is set by the Chipman Reservoir. The lowest elevation areas in the center of town have static pressure of about 135 psi. Many customers have individual pressure reducing valves.

The Town Water Department and the Middlebury College Facilities Services staff report that there is a water hammer issue in the system. Pressure gauges interior to some college buildings have measured pressures of 180-260 psi as documented by photographs taken by College Facilities Services staff on January 10, 2018. Normal static levels in this area are 100-110 psi.

Fire Flow Requirements

The most recent Insurance Services Office (ISO) testing was performed September 25, 2013. As shown in the tabulated results contained in the Appendices, the majority of the ISO Needed Fire Flows (NFF) are satisfied. At two locations, the Available Fire Flow (AFF) was less than the NFF. These locations are Foote Street/Dorey Lane and Route 116 at Specialty Filaments, shown in Figure 3.


LEGEND
WATER MAIN
ISO LOCATION WHERE NFF IS ACHIEVED
ISO LOCATION WHERE NFF IS NOT ACHIEVED
ISO #5 AFF 3300 GPM
ISO #4 AFF 650 GPM
ISO #12 AFF 3600 GPM
ISO #13 AFF 5700 GPM
ISO #11 AFF 19700 GPM
ISO #14 AFF 2600 GPM
ISO #3 AFF 2000 GPM ROUTE 116 AT SPECIALTY FILAMENTS
ISO #10 AFF 2000 GPM
ISO #15 AFF 1900 GPM FOOTE STREET AND DOREY LANE
ISO #2 AFF 2400 GPM
Chipman Hill
HAPPY VALLEY RD
ELLEN DR
PAINTER RD
Old Middlebury Cem
WASHINGTON ST EXT
QUARRY RD
WEYBRIDGE RD
PULP MILL BRIDGE RD
SEYMOUR ST
EXCHANGE ST
GORHAM LN
COLLEGE ST
Middlebury Coll
West Cem
S MAIN ST
PORTER FIELD RD
S ST EXT
CHARLES AVE
COURT ST
BUTTOLPH DR
ROGERS RD
CREEK RD
BOARDMAN ST
Foote Street Cem
FOOTE ST
S RIDGE DR
MIDDLE RD S
Otter Creek
CASE ST
Case Street Cem
Muddy Br
MUNGER ST
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SHEEP FARM RD
BICENTENNIAL WAY
Middlebury State Airport
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Project Mgr. K
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Checked by
Date 3/2018
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SECTION 2
EVALUATION
WATER MODELING AND HYDRAULIC EVALUATION REPORT
MIDDLEBURY, VERMONT

Demand Projections

Based on a 20-year planning period, future average day demand is estimated for the year 2038 by linearly projecting the current average day demand using an annual increase of 0.93%. This growth rate is equal to the historical system demand rate of increase over the 2007-2017 period. Based on this projection, the future average day demand in 2038 is estimated at 1.54 mgd.

The projected future demands are shown in Table 3. The future maximum day demand of 2.60 mgd is estimated by applying a peaking factor of 1.69 to the future average day demand. Peak hour demand is estimated using a peaking factor of 2.3 for the peak hour to average day ratio.

TABLE 3
FUTURE WATER SYSTEM DEMANDS

Period	Future (2038)
Average Day	1.54 mgd
Maximum Day	2.60 mgd
Peak Hour	2,460 gpm

Notes:
1. The average day demand was 1.27 mgd for the period 2015-2017 is based on total water production records.
2. Future average demands are calculated using an annual growth rate of 0.93%, equal to the historical demand increase trend over 2007-2017.
3. Maximum day demand is calculated using a peaking factor of 1.69 for average day to maximum day. Peak hour demand is calculated using a peaking factor of 2.3.

Water System Service Area

A water system service area represents the land that can be serviced at acceptable pressure without boosted pressure zones. Delineation of the practical upper limits of the service area for the Town of Middlebury was determined by an evaluation of the topography of the region and the following minimum pressure criteria in accordance with the Vermont Water Supply Rule (WSR):

- 20 psi minimum pressure at ground level throughout the distribution system at all flow conditions.
- 35 psi minimum normal working pressure.

The upper limit of the service area is usually defined as the maximum elevation where the minimum working pressure (35 psi) is maintained. The static pressure is usually set by adjacent distribution storage tanks and depends on storage tank levels. Typically, a low tank level is assumed for calculating the elevation corresponding to 35 psi (approximately 80 feet) below the lowest working level to allow for "active" storage tank level. Development above the elevation that corresponds to the defined service area limit is usually prohibited to ensure that users receive water at adequate pressures.

The overflow elevation of the existing 1.5 mg Chipman Reservoir storage tank sets the hydraulic gradeline for all customers served by gravity flow from this tank and defines the topographic limits that can be served by the proposed water system without pumping. The limit of the areas that can be served by gravity, based on the tank low level criteria is elevation 580 ft. The service area limit calculation is presented in Table 4 and shown in Figure 4.

Connection of future customers in the water system should be restricted to the 580 ft service area elevation. Customers above this elevation should not be serviced by the water system without use of municipal style water booster stations. As shown in Figure 4, there is one user on Springside Road that is just above the service area limit at elevation 595 ft. The normal static pressure at this location is 30 psi.

TABLE 4
MAXIMUM GRAVITY
SERVICE AREA LIMITS

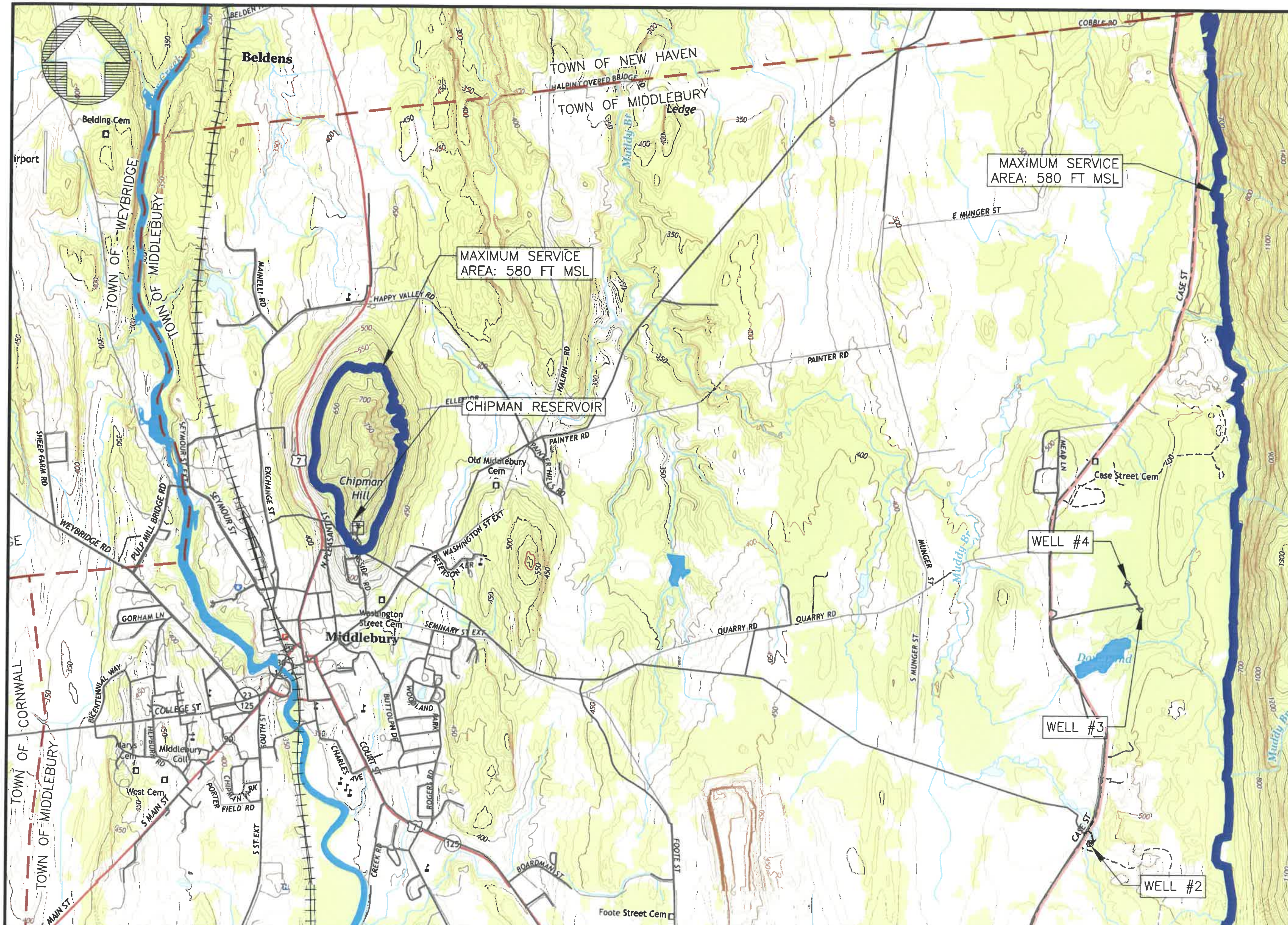
Item	Value
Maximum Hydraulic Gradeline	666.8 ft
Tank Low Level Alarm from Overflow	-4 ft
Minimum Working Pressure (35± psi)	- 80.9 ft
Service Area Maximum Limit (approximately)	580 ft

Notes:
1. The maximum hydraulic gradeline is set by the overflow elevation of the existing Chipman Reservoir storage tank.
2. Tank level fluctuation is based on a level of 13.25 ft in the storage tank, 0.75' below the normal Well 2 control "On" setting of 14 ft.
3. Minimum working pressure is defined by the Vermont Water Supply Rule.

Storage Volume Requirements

The Vermont Water Supply Rule provides criteria for sizing finished water storage facilities for systems providing fire protection as the volume necessary to meet the following:

- Fire flow demands of a minimum of 500 gpm for two hours with consideration for fire flows established by the Insurance Services Office (ISO) or the local fire department.
- Average daily domestic demands.



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MAXIMUM WATER SYSTEM

MIDDLEBURY, VERMONT

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The criteria does not include a requirement for peak flow equalization volume. In addition, this criteria does not address or consider that a portion of the tank may be unusable or require "dead storage" to maintain minimum system pressure for protection of high elevation customers.

Prior to defining the storage components, the following functions of storage facilities should be considered:

1. Storage tanks cannot compensate for inadequate source capacity. The only water available from a tank during the day is the quantity that can be replenished at night. If daily demands exceed the source capacity for an extended period, the storage tanks will eventually be empty regardless of the tank size.
2. Water storage tanks provide water to meet system demand during emergency periods when sources of supply are not available.
3. Peak hourly and fire flow demand usually exceeds total source capacity and is generally provided from water storage, which is replenished during low demand periods.
4. Storage facilities stabilize the system's hydraulic gradeline providing steady pressures to areas adjacent to the tanks during variable demand conditions.
5. Water storage tanks should be located at an elevation at least 80 feet above the highest customer to provide a minimum pressure of 35 psi to the highest user at the tank low operating level.
6. Storage tank sizing should consider the effect of oversized tanks on increased detention times and potential water quality issues.

In considering the functions listed above, the storage volume for a single tank generally consists of the following components:

<u>Peak Flow Equalization:</u>

Water storage facilities should be designed to provide equalization between average day and peak hourly demands, with water withdrawn from storage during peak demand hours and replenished during nighttime, low demand periods. If there is not adequate storage to provide peak hour demands, source facilities must meet the peak flow requirements.

The amount of water produced that should be stored for equalization depends on the individual system and typical operations. For example, in a system where pumps are operated continually to meet the average demand for the day, many references refer to a general rule of providing 10-25% of maximum day demand exclusively for the peak flow equalization volume component.

Emergency Storage:

Emergency storage is provided in order to maintain continuous water service during short periods without source availability due to equipment maintenance or transmission main disruption and repair. Typically, this volume is equal to one day of average day system demand, but it is usually greater for systems with a vulnerable water supply. The volume of emergency storage is larger for systems with few sources and no auxiliary power supply, compared to systems with multiple sources and backup power.

Fire Flow Protection:

The rates of flow to be available for fire suppression concurrently with normal system usage are typically far in excess of source and/or treatment capacity. Generally, it is much less expensive to construct water storage facilities to provide fire flows than to construct high capacity source facilities, which would otherwise be required.

In accordance with the Water Supply Rule, the amount of fire flow storage for individual systems should consider ISO criteria. However, this requirement does not provide for a quantified design criterion. Historically, ISO has developed fire flow rates for selected individual buildings but does not set fire flow durations. However, the National Fire Protection Association does provide fire flow durations, which can be used to estimate fire flow volumes in conjunction with the ISO fire flows. Interpretation by the local fire chief is usually required to quantify a required volume and to confirm the required fire flow for the community.

The Town of Middlebury Fire Chief has established the local fire flow requirement is the ISO fire flows, which include Needed Fire Flows (NFF) of 3,500 gpm.

Dead Storage:

Dead storage volume is the water that must remain in a tank to ensure customer pressures are at least 35 psi during normal conditions or at least 20 psi under all flow conditions including a fire situation. This volume is variable for each tank depending on the highest customer in the tank service area, the tank elevation and the tank configuration. Typically, this volume is most significant in tall standpipe tanks.

There is one user above the maximum service area set by the 35 psi minimum pressure criteria at elevation 580 feet. Even with a full tank, this user has just 31 psi water pressure. Therefore, there is no benefit to maintaining a partially full tank just to keep high elevation users above 35 psi.

Table 5 presents an analysis of required storage tank volume based on current demands. However, it would not be cost efficient to build a water storage tank to meet existing conditions only. Storage tanks can last for decades and in most cases, it makes economic sense to build larger tanks to meet future conditions. Therefore, the analysis also presents the future scenario based on future demands.

TABLE 5
STORAGE TANK VOLUME ANALYSIS

Component	Current Scenario Volume (mg)	Future Scenario Volume (mg)
Existing Tank Storage - Dead Storage	1.50 -0.00	1.50 -0.00
Available Storage	1.50	1.50
Peak Flow Equalization Emergency Storage Fire Flow Protection	+0.52 +1.24 +0.63	+0.62 +1.53 +0.63
Total Storage Recommended	2.39	2.78
Storage Surplus (+) or Deficit (-)	0.89	1.28

Notes:

1. Peak flow equalization = 25% of Maximum Day Demand.
2. Emergency storage = 100% of ADD.
3. Fire flow protection = 3,500 gpm for 3 hours.
4. Dead storage is zero since existing users have insufficient pressure even with a full tank and providing a dead storage volume has no benefit.

The analysis shows that 2.78 mg of storage is required for the system to provide the storage volume components of equalization, emergency and fire flow protection based on a 3,500 gpm fire flow and future demand projections. In comparison to the required 2.78 mg, the storage provided by the existing 1.5 mg tank is deficient, with a difference of 1.28 mg between available and required storage volume.

In addition to the individual volume components discussed above, there are other considerations in selecting the storage volume for this project. In some systems with disinfection byproduct (DBP) issues, there is concern of providing too much storage due to water age and the related disinfection byproduct formation potential. In those situations, mixing and other techniques are used to reduce DBP formation. Although Middlebury has not experienced DPB issues, incorporating mixing techniques should be considered for the tank design. This may be as simple as a separate inlet, elevated above the outlet at the tank floor, or installing a mechanical mixer such as the GridBee system.

Distribution System Hydraulic Evaluation

A model of the water system was developed using Bentley Haestad Methods WaterGEMS® computer software. GIS files for the system water pipes provided by the Town were used to create the water model. The pipes included attribute data for pipe diameter, material and age. Additional information was added to the pipe data to define roughness coefficients. Other model input included system demands, pump characteristics curves, tank geometry and elevations.

The model was calibrated to actual field testing by Dufresne Group in July 2018. A calibration report, which documents the model development and calibration procedures is included in the Appendices.

The computer model was used to identify existing areas of inadequate pressure based on the Water Supply Rule criteria that a minimum pressure of 20 psi shall be maintained at all points under all conditions of flow and a minimum pressure of 35 psi under normal conditions.

The calibrated computer model of the water system was also used to simulate existing conditions during average day demand (normal conditions) and the system design flow. The design flow represents the limiting condition, which is the greater of peak hour demand or a fire flow during maximum day demand. For the Town of Middlebury, the limiting condition is system maximum day demand in conjunction with fire flow demand. Fire flow demands were based on the Insurance Services Office (ISO) fire flows.

During present and future average day and maximum day demand conditions, without a fire flow, there are no pressure problems. During simulations of a 500 gpm minimum required fire flow during present system maximum day demand, there are only a few locations where a 500 gpm fire flow cannot be satisfied. These locations, shown in Figure 5, are:

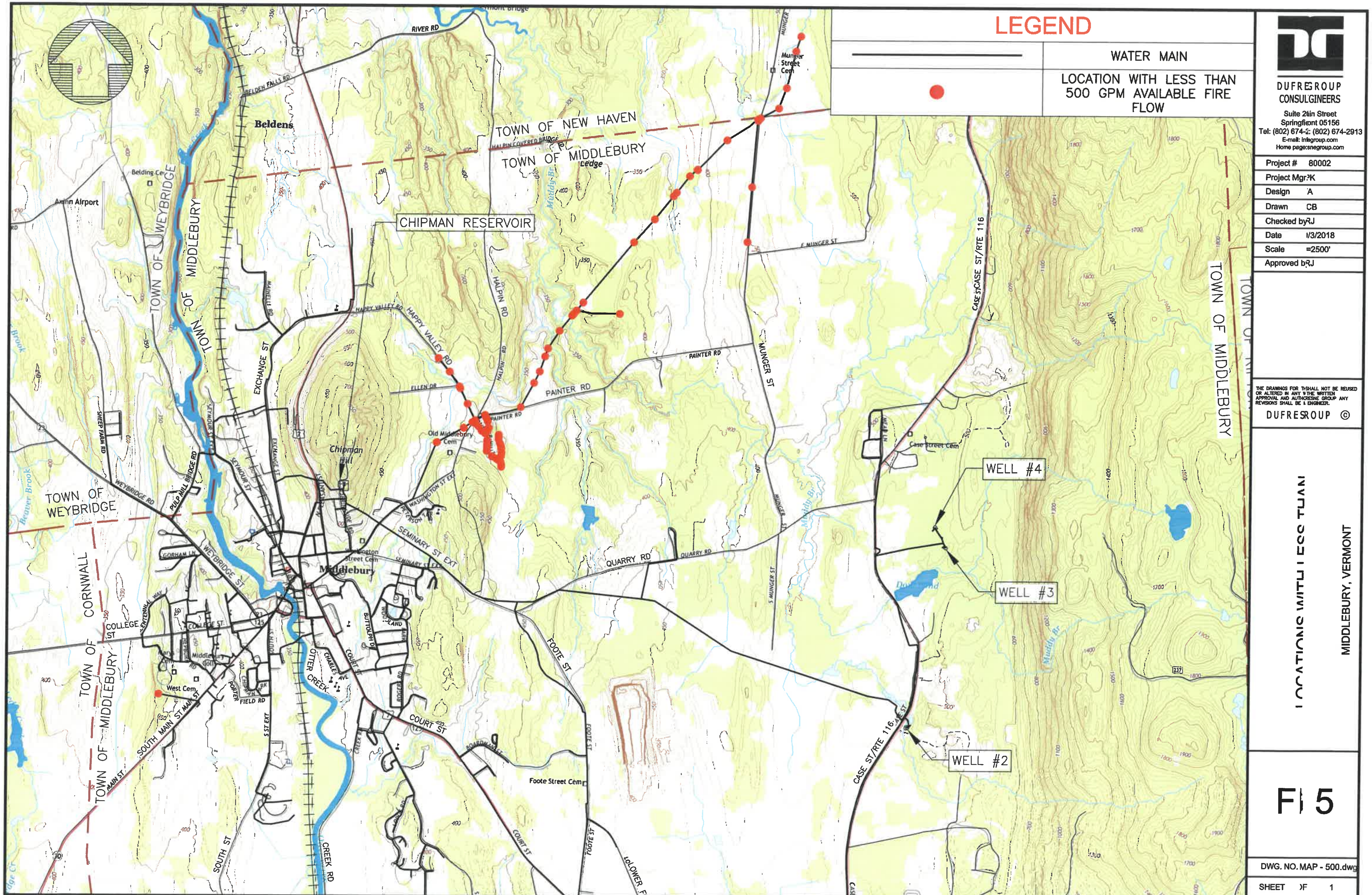
- The end of the 4-inch diameter main west of South Main Street.
- Painter Hills Road and Happy Valley Road region.
- Munger Street.

The water model was used to simulate the 2013 Needed Fire Flows. During simulations of the fire flows during future maximum day demand, there are two locations where the flow cannot be achieved while maintaining a minimum of 20 psi at all locations in the distribution system that are normally above 35 psi.

These locations are on Case Street and Foote Street. The Foote Street fire flow does not adversely affect areas in the distribution by causing pressures to drop below 20 psi. The needed fire flows at Painter Road/Painter Hills Road and Case Street are the only ISO locations that have NFFs which cause pressures below 20 psi. Figure 6 depicts the water model node locations that fall below 20 psi during the simulated Needed Fire Flows.

Potential for Microelectric Generation

There is no excess available head within the hydraulic gradeline from the sources to distribution system to allow for hydroelectric generation from the existing system. If there were pressure reducing valves (PRVs) that reduced the gradeline from one pressure zone to a second zone, that situation would provide the opportunity to use the wasted head from pressure reduction for hydroelectric generation. However, there are no PRVs in the Middlebury system.


LEGEND
WATER MAIN
LOCATION WITH LESS THAN 500 GPM AVAILABLE FIRE FLOW
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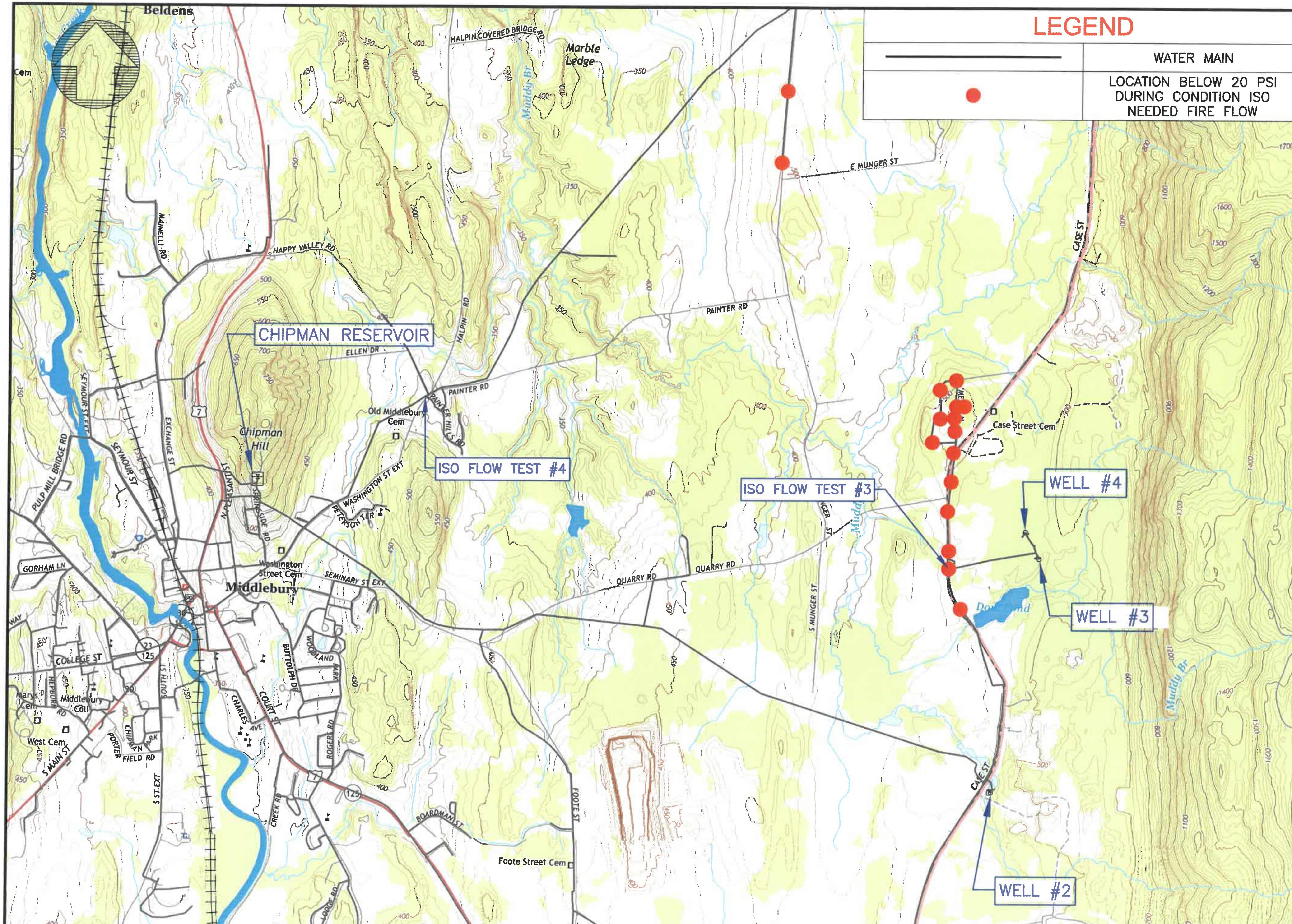
COLLEGE ST
Middlebury
Beldens
Chipman Hill



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Surge

Pressure recording data shows that two significant pressure fluctuations occurred during five weeks of monitoring in June and July 2018, with drops of about 50 psi. These two events were on June 13, 2018 at 10 a.m. and June 14, 2018 at 8 a.m. A copy of the chart is included in the Appendices.

The pressure recordings do not show high pressure swings that would occur in the event of a water hammer. The well operation data for these two days was reviewed to assess if well pump on/off operation coincided with the pressure fluctuation. The data shows the on/off times do not correspond to the time of the pressure drops.

On-line meter records were reviewed for customers with large diameter meters including the college and Vermont Apple Cider. The records show no major changes at the time of the pressure drop when compared to values throughout the June 13-14 time period.

As described previously, pressure spikes to 260 psi have been documented on the college campus. This is a significant issue to be resolved. Continued pressure monitoring should occur in an effort to identify the time of day of the surges and potential causes. Since there were no surges in the June-July monitoring period, it appears the water hammer events occur when college is in session. Dufresne Group can provide a pressure chart recorder for further investigations of pressure fluctuations.

Summary of Deficiencies

The water system modeling results, analysis of water storage and review of existing system characteristics identified the following deficiencies:

1. One water customer at 19 Springside Road is above the existing service area and has normal working pressure below the required 35 psi minimum.

2. The required minimum 500 gpm fire flow is not achieved at the following locations:

    a. The end of the 4-inch diameter main west of South Main Street.
    b. Painter Hills Road and Happy Valley Road region.
    c. Munger Street.

3. During ISO fire flow conditions, 20 psi minimum pressure is not maintained at the following locations:

    a. Case Street (during 3,500 gpm NFF at 3406 Case St)

b. Painter Hills Road, Happy Valley Road and Munger Street (during 500 gpm NFF at Painter Rd. and Painter Hills Rd.)

4. The Needed Fire Flows at Case Street and Foote Street are not available.

5. The storage tank volume is inadequate to provide current or future average day demand plus fire flow volume. The deficit is 1.3 mg for the future demand condition.

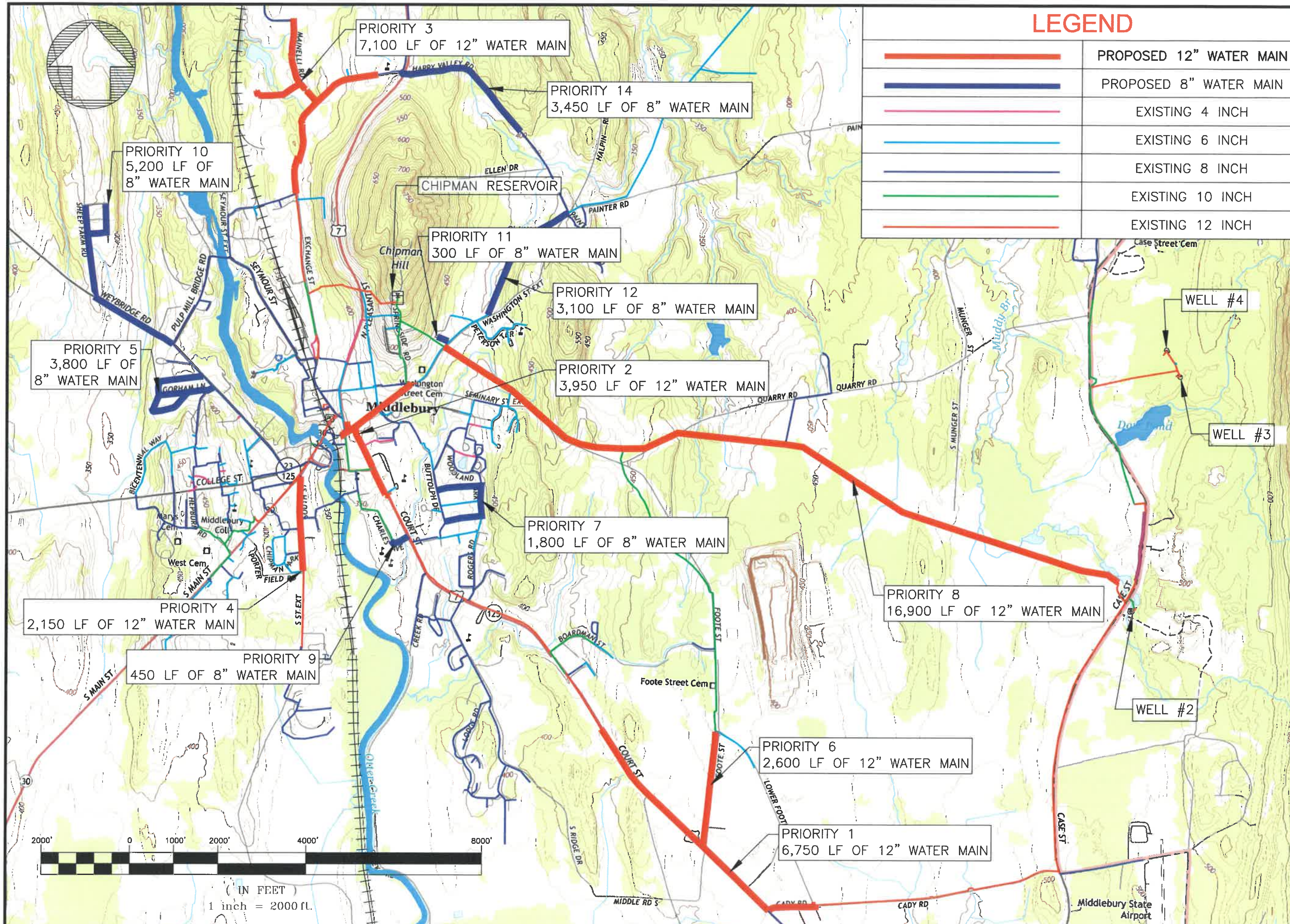
6. Water hammer is causing high pressure surges in excess of 250 psi.

Assessment of Improvements

Middlebury Water Department staff have developed a list of priority water main replacement projects. The projects are identified as high priority to address areas of known leakage, undersized pipes and aged infrastructure. Table 6 presents the 13 projects identified by the Town. These projects are shown in Figure 7.

TABLE 6
TOWN PRIORITY PROJECTS

Town Priority Rank	Location	Proposed Diameter (in)	Length (ft)
1	Route 7/Cady Road/Court St.	12	6,750
2	Court Square and Washington Street	12	3,950
3	Exchange Street, Mainelli Road, Pond Lane	12	7,100
4	South Street	12	2,150
5	Gorham and South Gorham Lane	8	5,200
6	Foote Street	12	2,600
7	Woodland Park, Meadow Way, Swanage Court	8	2,700
8	Seminary Street Ext. and cross country	12	16,900
9	Charles Avenue	8	450
10	Sheep Farm Rd and Weybridge Street	8	5,200
11	Colonial Drive	8	300
12	Washington St Ext	8	3,100
13	Happy Valley Road	8	3,450



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TOWN PRIORITY

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SHEET F 1

The water main replacement projects were simulated in the water model to evaluate the effect of the improvements on existing system deficiencies. Since there are few pressure deficiencies, the effect of the improvements to resolve the problem areas is limited. The effects are summarized as follows:

1. Priority projects 1 and 6 (Route 7/Court Street and Foote Street): increases the available fire flow and resolves the deficient fire flow condition at Foote Street.

2. Priority project 12 (replace the 6-inch main cross country off Washington Street extension with 8-inch diameter pipe): increases the available fire flows in the Painter Hills Road region and the 500 gpm minimum fire flows are achieved.

3. Priority project 13 (Happy Valley Road loop): increases the available fire flows in the Painter Hills Road region and the 500 gpm minimum fire flows are achieved.

With all of the proposed improvements on the Town's list incorporated into the water system, the following distribution system hydraulic deficiencies remain:

- A 3,500 gpm fire flow at the 3406 Case Street causes pressures to fall below 20 psi north of the fire flow location.
- A minimum fire flow of 500 gpm cannot be achieved at Munger Street.

System hydraulics may be improved with the construction of a second water storage tank, which has been identified as a needed improvement. There are two general locations in Middlebury that have adequate elevation to site a ground level storage tank. The first location is Chipman Hill and the second is east of Case Street. Additional storage on Chipman Hill would address the storage deficit but not resolve the fire flow issue on Case Street.

The Town has previously identified the parcel owned by A. Johnson Co., LLC off School House Hill Road, east of Case Street, as a potential water storage tank site. The suitable elevation of a tank on the east side of the water system, near the well sources of supply, is dependent on the characteristics of the well pumps and the transmission mains. The tank must be low enough to be filled by the well pumps and high enough to maintain adequate gradeline for the system when the wells are off.

The 580 ft service area limit defined by the Chipman Reservoir bisects this parcel from north to south. But, this limit is set by the Chipman Reservoir remotely located from the potential new tank site. Due to the distance of the potential new site from the distribution system and the resulting headloss in the transmission main, the tank must be located above elevation 580 ft.

A proposed tank on the Johnson parcel was simulated to assess the effect on system pressures during fire flow conditions in the north Case Street area. Based on preliminary modeling using Extended Period Simulation techniques, the proposed tank was simulated with a floor elevation of 680 ft and an overflow elevation of 700 ft. The tank improved the available fire flow at 3046 Case Street to 3,675 gpm but did not resolve the pressure deficiencies during the fire flow condition. Resolution of the Case Street pressure issues would be resolved with construction of a tank closer to the fire flow location to reduce the pressure drop during a 3,500 gpm fire flow. A review of topographic mapping shows there are no locations with elevation around 700 ft that provide a substantial wide, level area for a potential tank site as is available on the Johnson parcel. There is a sizeable pond adjacent to the fire flow location that has the potential for use as a source during a fire event. The Johnson tank site is shown in Figure 8.

Regarding the remaining distribution system deficiencies, the computer modeling was used to develop the following findings:

1. The Munger Street pressure deficiencies are resolved by replacing all the 6-inch diameter pipe on Washington Street and the cross country route with 8-inch diameter main, a total length of about 15,000 ft.
2. Replacement of the section of 4-inch main west of South Main Street increases the available fire flow to a minimum of 500 gpm.

Considerations for Project Planning and Cost Estimates

The Town's list of planned water main replacement projects was developed to address known leakage, undersized pipes, deficient materials and aged infrastructure. The Town Water Department routinely repairs more than 20 pipe breaks each year, therefore replacement of the pipes prone to leaks is high priority.

Pipe condition has been a major factor in assigning priority to the replacement projects. Since fire flow availability is generally good, replacement to address hydraulic issues has been a lesser factor in recent project planning. One of the objectives of the system modeling is to identify hydraulic issues that may revise the original priority for water main projects.

Another factor that was considered in the distribution system evaluation is the ability of the system to provide for projected growth. As described by Town representatives and also discussed in the Town Plan, the primary area for potential growth is the industrial area off Exchange Street. The priority 3 project provides a strong water main connection to this area, with all 12-inch diameter water main except for one segment of 10-inch diameter piping on Route 7.

Based on the results of the distribution hydraulic evaluation, there are no recommendations for revising the priority ranking for water main replacement projects. The improvements described above to improve hydraulics for the Munger Street area during the fire flow conditions are not included as recommended capital improvements, primarily because the expense does not appear justified compared to the relatively

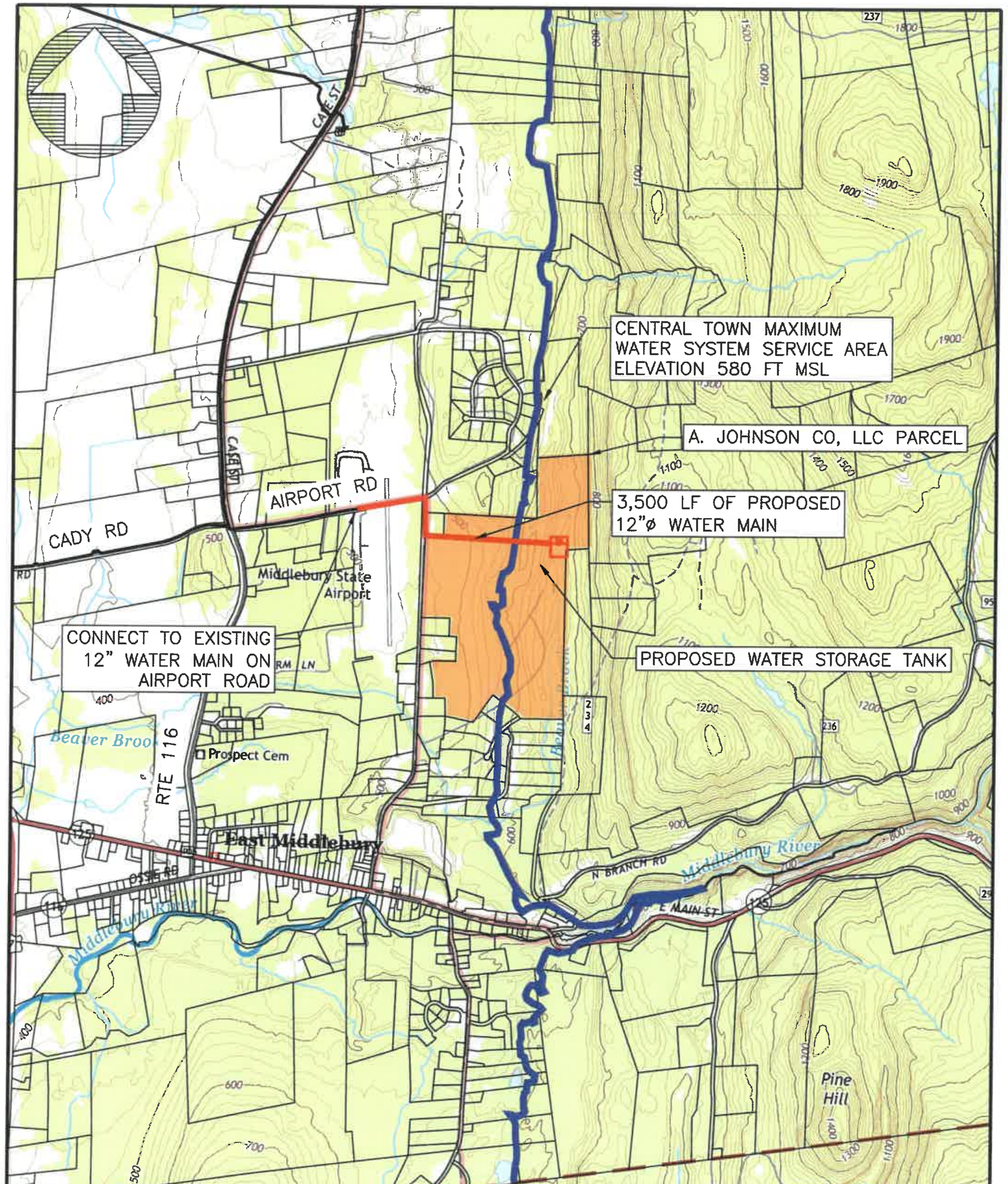

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FIGURE 8

POTENTIAL SITE
WATER STORAGE TANK
JOHNSON PARCEL

MIDDLEBURY, VERMONT

PROJECT NO. 4180002
PROJECT MJR. TPK
SCALE 1"=2000'
DATE 10/3/2018
DRAWING NO. Parcel Map.dwg

minor benefit. Replacement of the 4-inch main is also not a priority project since there are hydrants in the vicinity that may serve the area with adequate flow. However, a new water storage tank and transmission main is added to the list of planned capital improvements. The priority of this project will be reviewed by Town staff, but the priority is considered high and in the top three projects.

The construction and capital costs for the water improvements projects are shown in Tables 7 and 8. These costs are based on current construction prices and must be inflated for future years.

TABLE 7
WATER MAIN REPLACEMENT PROJECTS ESTIMATED COSTS

Location	Existing Pipe	Proposed Diameter (inches)	Length (ft)	Cost Per Foot	Estimated Construction Cost	Total Project Cost
Route 7/Cady Rd./Court St.	6-10" CI	12	6,750	$250	$1,687,500	$2,379,000
Court Square and Washington St.	6-12" CI and DI	12	3,950	$250	$987,500	$1,392,000
Exchange St, Mainelli Rd, Pond Lane	12" DI	12	7,100	$250	$1,775,000	$2,503,000
South St.	4-6" CI	12	2,150	$250	$537,500	$758,000
Gorham Lane and South Gorham Lane	2-6" Universal	8	5,200	$225	$1,170,000	$1,650,000
Foote St.	6" CI	12	2,600	$250	$650,000	$917,000
Woodland Park, Meadow Way, Swanage Court	6" AC	8	2,700	$225	$607,500	$857,000
Seminary St. Ext. and cross country	10" CI	12	3,500	$250	$875,000	$1,234,000
	10" CI	12	13,400	$200	$2,680,000	$3,779,000
Charles Avenue	6" CI	8	450	$225	$101,250	$143,000
Sheep Farm Road and Weybridge St	6" CI	8	5,200	$225	$1,170,000	$1,650,000
Colonial Drive	2" PVC	8	300	$250	$75,000	$106,000
Washington St. Ext.	6" CI	8	3,100	$225	$697,500	$983,000
Happy Valley Road	None	8	3,450	$225	$776,250	$1,095,000

Notes:

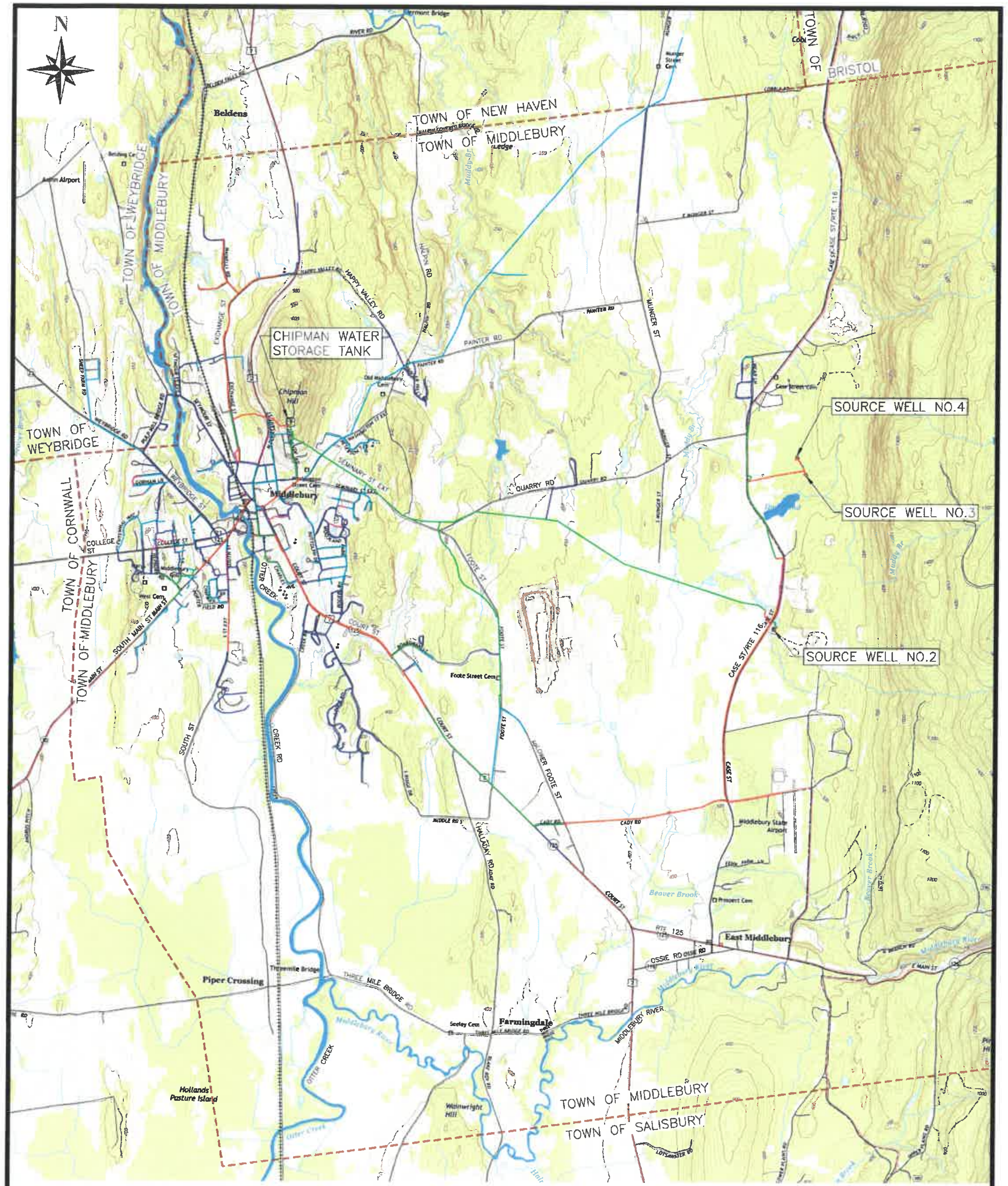
1. Unit prices are based on manufacturers' quotes, RS Means pricing and bid tabulations for recent projects. The estimates are made without the benefit of final design and actual costs may vary substantially. The cost estimates are dated October 2018, ENR = 10,900.
2. The project on Seminary St. and a cross country rate includes 13,400 lf of cross country main. This section has a reduced cost per foot since pavement restoration is not required. The cost assumes pavement restoration is trench patch, not full width overlay.
3. Costs per foot include complete construction of water main and appurtenances, surface restoration (with trench patch in paved areas) traffic control and contractor overhead/profit.
4. The total project cost consists of construction cost plus administrative, engineering and contingency costs. Administrative, engineering and contingency costs are all estimated as a percentage of construction, with values of 3%, 23% and 15% respectively.

TABLE 8
PROPOSED WATER TANK ESTIMATED CONSTRUCTION COSTS

Item	Quantity	Units	Cost
1.3 mg Tank	1	LS	$1,000,000
Tank Accessories	1	LS	$35,000
Site Work and Yard Piping	1	LS	$150,000
Geotechnical Investigation	1	LS	$10,000
2,000 lf Access Road	1	LS	$200,000
3,500 lf Transmission Main	1	LS	$790,000
Miscellaneous Work and Cleanup	1	LS	$325,000
Total Construction Cost			**$2,500,000**
Total Project Cost			**$3,525,000**

Notes:

1. Unit prices are based on bid tabulations for recent projects, cost estimates in RS Means and pricing from DN Tanks received October 2018 for a 30' high, 86' diameter precast-prestressed concrete tank. The estimates are made without the benefit of final design and actual costs may vary substantially. The cost estimates are dated October 2018, ENR = 10,900.
2. The 1.3 mg tank concept is a precast-prestressed tank with an 86 ft diameter and 30 ft water depth. The cost for tank and accessories is based on an October 2018 quote from DN Tanks. Glass-fused-to-steel tanks are also feasible, economical and recommended for consideration.
3. The total project cost consists of construction cost plus administrative, engineering and contingency costs. Administrative, engineering and contingency costs are all estimated as a percentage of construction, with values of 3%, 23% and 15% respectively.



MIDDLEBURY, VT
WATER SYSTEM BASEMAP
LAST UPDATED: APRIL 25, 2018

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