Permit Renewal Planning for Westborough: Integrated Assessment and Basin-Wide Training

Sustainable Water Management Initiative Grant:
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Submitted by:

Town of Westborough, MA

Abt Associates Inc.

OARS

Executive Summary

The Commonwealth of Massachusetts (the Commonwealth) promulgated revisions to the Water Management Act (WMA) regulations (the Regulations) in 2014 that seek to balance protecting the health of water bodies with meeting the needs of communities for water by implementing sustainable water management. The revisions include changes to the Massachusetts Department of Environmental Protection (MassDEP) process for reviewing and granting water withdrawal permits and actions required to minimize the existing impact of withdrawals and mitigate the impact of increases in withdrawals.

The objective of this planning study was to determine the least-cost combination of management actions that will meet both the Town of Westborough's (Westborough) current and projected water needs and the Regulations. We assessed potential compliance actions for meeting requirements in the four existing source subbasins in the Concord Basin – subbasins 12010, 12020, 12026, and 12027 – hereafter referred to as Chauncy, SuAsCo, Jackstraw, and Sandra, respectively. We used the U.S. Environmental Protection Agency (EPA)'s Watershed Management Optimization Support Tool (WMOST) to screen and assess the relative cost-effectiveness of potential actions. We also provided a training session to other towns in and around the Concord Basin on the new Regulations and the various decision-support tools available for water supply planning. The results of the planning study were presented to the Westborough Selectmen at a public meeting.

The Westborough Department of Public Works (WDPW) delivers an average of 2.3 million gallons per day (MGD) of water to Westborough residents and commercial and industrial customers. MassDEP provided an interim water needs forecast for the next 20-year permit period of 3.1 MGD, which is the same as the current authorized volume of all municipal withdrawals. WDPW uses nine groundwater wells and one reservoir across the four source subbasins to meet demand. Approximately 10 percent of customers are on septic systems and 90 percent are sewered. The Westborough Wastewater Treatment Plant (WWTP) receives water from Westborough, Shrewsbury, and Hopkinton. It is located in the SuAsCo subbasin where it discharges an average of 5.3 MGD of treated effluent.

The Regulations apply to permitted withdrawals. Westborough has permitted groundwater withdrawals in two of its four source subbasins – Chauncy and SuAsCo. The Jackstraw and Sandra subbasins only have registered withdrawals and therefore are not subject to the Regulations. MassDEP has designated the Chauncy and SuAsCo subbasins as August net groundwater depleted (ANGD). In addition, the SuAsCo subbasin contains coldwater fishery resources (CFRs).

In Chauncy, pumping during 2010-2014 was significantly different than during the Regulations' baseline period of 2000-2004. WDPW may submit this change in pumping allocation among source subbasins as a Data Refinement.[1] If accepted by MassDEP, WDPW may not need to implement minimization actions in Chauncy.

The SuAsCo subbasin receives discharges from Westborough's WWTP that are in excess of the water withdrawals from the subbasin. "Wastewater discharges that result in improvements to the quantity and timing of streamflow" are an acceptable minimization action.[2] The WWTP discharges upstream of some wells and downstream of others. The Regulations are not specific about the required location of the wastewater discharge to qualify for minimization and Westborough may therefore need to implement

[1] Section 10 of the WMA Permit Guidance Document (MassDEP, 2014)

[2] Section 6b of the WMA Permit Guidance Document (MassDEP, 2014)

other actions to minimize its existing impacts in the subbasin if MassDEP determines that the WWTP discharge is not an eligible minimization action. For this study, we assessed the possibility of source optimization (i.e., shifting pumping to other source subbasins) and surface water releases from the SuAsCo Reservoir. These analyses provide a range of potential strategies for minimization in the SuAsCo subbasin that may be selected depending on discussions with MassDEP. For the CFR requirements, we examined the Zone II delineation of SuAsCo wells and determined that wells located adjacent to the SuAsCo reservoir are subject to CFR consultation and source optimization. The actions evaluated for minimization including source optimization are applicable for a CFR protection strategy.

MassDEP allocated 2.30 MGD to WDPW as baseline withdrawal.[3] In the past five years, WDPW's average withdrawal levels were near this baseline, ranging from 1.99 to 2.23 MGD. Several measures are available, and some required, that may keep demand below 2.30 MGD in the near future, including the standard conditions discussed in Section 2.2 and initiating a water efficiency program. Demand management or water efficiency is required before withdrawals above baseline and commensurate mitigation is allowed. We estimated the demand reduction potential of a water efficiency program over the first years of the permit, prior to permit review. We estimated a potential savings of 0.10 MGD at an annual cost of less than $3,000.

For the longer term planning required for the 20-year permit renewal, WDPW may request to renew its previously authorized volume of 3.10 MGD. At this volume, WDPW will need to implement mitigation measures to offset 0.80 MGD. Several options exist for mitigation. First, withdrawals from Indian Meadows well are offset by the Westborough wastewater treatment plant. Indian Meadows has had water quality issues but if this well is connected to the Fisher street water treatment plant, then this well could be pumped up to its authorized volume of 1.13 MGD without mitigation actions. Second, WDPW can withdraw additional water from the Jackstraw and Sandra subbasins without mitigation because these are registered sources and not subject to the Regulations. Meeting standard conditions, initiating a water efficiency program and allocating additional withdrawals to the Indian Meadows well and/or Sandra and Jackstraw subbasins will meet WDPW's requirements.

However, the two subbasins with registered sources contain designated CFRs and discharge to Cedar Swamp, which is an Area of Critical Environmental Concern (ACEC).[4] We therefore evaluated additional scenarios to reallocate pumping among source subbasins, improve aquatic habitat in these two subbasins and protect the critical habitat of Cedar Swamp. WDPW, MassDEP, OARS and other stakeholders may wish to discuss acceptable terms for enhancing these aquatic resources while maintaining WDPW's access to its registered withdrawal volumes.

Data refinement calculations and WMOST modeling discussed in this study are planning-level analyses. The study used estimates from previous WMOST applications, literature values and approximate values from WDPW for some model inputs. The results are reliable and accurate to the extent that the input data are reliable and accurate (e.g., cost and effectiveness of practices, runoff/recharge time series). In addition, we made several assumptions about regulatory requirements and applicable management

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3 This volume is the town's water use in 2005 plus five percent.

4 Cedar Swamp was the first Area of Critical Environmental Concern designated in Massachusetts. The approximately 1650 acres are primarily vegetated wetlands, providing critical flood water storage capacity for the Sudbury River basin and baseflow to the Sudbury River which experiences seasonal low flows. The area is the headwaters of the Sudbury River and overlays the medium- and high-yield aquifers that supply two public wells for Westborough. http://www.mass.gov/eea/agencies/dcr/conservation/ecology-acec/cedar-swamp.html

practices for meeting those requirements which we discuss in the main report. These factors are all important to keep in mind when considering the results, conclusions, and recommendations offered.

Acknowledgements

The project team would like to thank the municipal staff and consultants from water, sewer, public works, engineering, conservation and planning departments that made this effort possible. They invested considerable effort in sharing their knowledge of their systems, their data and the studies about the community they serve. We also thank the Westborough Fire Department for use of their facilities for the training workshop. We are grateful to the state agency staff at MassDEP, Department of Conservation and Recreation, the Massachusetts Water Resources Agency and the Central Massachusetts Regional Planning Commission for providing additional data that supported this effort. The primary authors of this report were Viki Zoltay and Annie Brown of Abt Associates. The project team also included Carl Balduf, Westborough Town Engineer, and Alison Field-Juma and Suzanne Flint of OARS.

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Table of Contents

1 Background

The Westborough Department of Public Works (WDPW), Abt Associates, and OARS (the Project Team) are pleased to submit this report in satisfaction of the Sustainable Water Management Initiative (SWMI) Grant to assess the implications of the revised Water Management Act (WMA) regulations (the Regulations) on the planning, operations and management of the water resources of the Town of Westborough, Massachusetts, and to identify cost-effective ways to meet both human and environmental water needs. In addition, we developed materials and conducted a training workshop for Westborough and other WMA permittees in and adjacent to the Concord Basin to enable them to use existing tools to assess requirements applicable to their permits, and to perform analyses to determine cost-effective strategies for meeting those requirements. Workshop materials and the public meeting presentation are provided as attachments to this report and are available on Abt Associates and OARS websites.[5]

This report is organized as follows:

- Section 1 provides a summary of the requirements under the revised WMA and describes the WDPW water system and its subbasins.
- Section 2 provides an analysis of the WMA requirements for WDPW and cost-effective actions to meet the requirements. We also assess additional scenarios for pumping allocation among subbasins that may enhance critical aquatic resources. Throughout Section 2, we utilize EPA's WMOST for comparing the cost-effectiveness of potential actions and discuss modeling results as appropriate.
- In Section 3, we summarize a strategy for WDPW to cost-effectively meet WMA requirements.
- Appendices provide additional details on modeling input data, process and results.

1.1 Water Management Act

The Water Management Act of the Commonwealth of Massachusetts (the Commonwealth) was first promulgated in 1986 to regulate withdrawals greater than 100,000 gallons per day. Withdrawals that were registered during the registration period of 1981-1985 are not regulated under the WMA; however, withdrawals authorized since 1986 are regulated. In 2014, the Commonwealth revised the Regulations, which seek to balance protecting the health of water bodies with meeting the needs of communities for water by implementing sustainable water management.[6] The revisions include changes to the Massachusetts Department of Environmental Protection (MassDEP) process for reviewing and granting water withdrawal permits and actions required to reduce the environmental impact of withdrawals.

All permittees must meet standard permit conditions. These standard conditions include performance requirements such as residential per capita water use levels and percent of unaccounted for water (UAW), minimum water conservation best management practices (BMPs) that include leak detection and repair, metering, and others, and limits on non-essential outdoor water use.

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5 See www.abtassociates.com/wma and www.oars3rivers.org/.

6 Water Management Act (MGL 21 G) Regulation (310 CMR 36.00), http://www.mass.gov/eea/agencies/massdep/water/regulations/310-cmr-36-00-the-water-management-act-regulations.html#2

The Regulations include specific protections for Coldwater Fishery Resources (CFRs). These are the smaller tributary streams that contain the conditions for and/or populations of coldwater fish, such as brook trout. These streams play a key role in supporting the ecological health and hydrological function of watersheds. Permittees with withdrawals in subbasins with CFR must consult the Commonwealth and evaluate reducing impacts through pumping optimization and other means.

MassDEP has identified subbasins that are August net groundwater depleted (ANGD) – where the net of groundwater withdrawals and groundwater returns are 25 percent of more of the subbasin unimpacted flow. Permittees with sources in ANGD subbasins have to minimize “existing impacts to the greatest extent feasible.” Minimization actions may include optimization of the existing water system or alternative sources including interconnections, additional conservation measures, and water releases and returns.

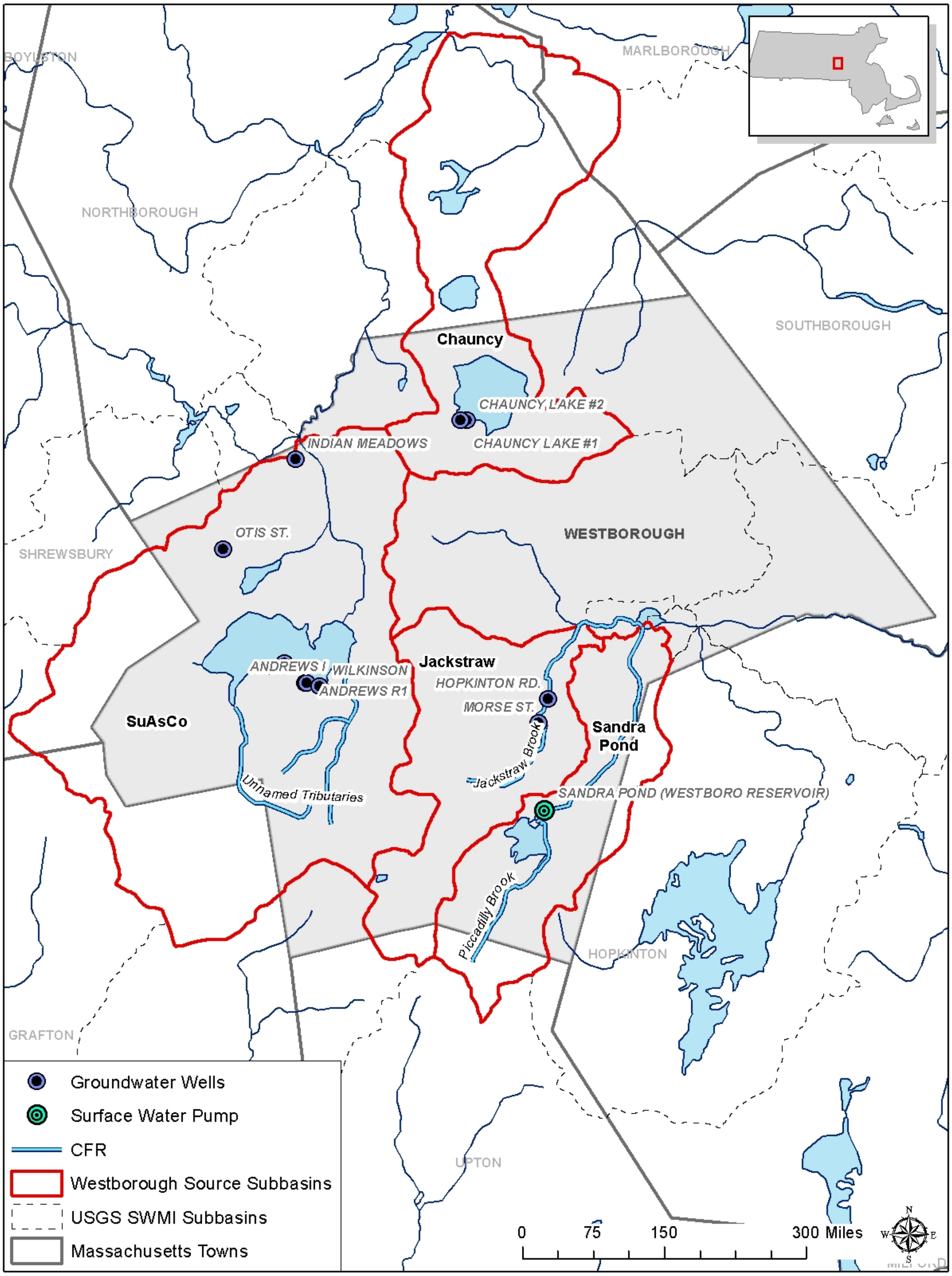
MassDEP allocated “baseline withdrawals” to each permittee. Permittees requesting withdrawals above baseline despite demand management will have to mitigate the additional withdrawals “commensurate with impact.” These changes will affect planning decisions by cities and towns on how best to meet current and future water needs. The WMA guidance specifies planning priorities (MassDEP, 2014). First, all feasible options for demand management must be implemented. If mitigation is still required, then direct mitigation should be prioritized over indirect actions. Direct mitigation is defined as actions whose impact can be volumetrically quantified. Finally, permittees may be asked to demonstrate no feasible alternative sources based on the requested volume above baseline and the “remaining volume” in the source subbasin before a change in its Biological Category (BC) or Groundwater Impact Category (GWC).[7]

1.2 Town of Westborough and Its Water Supply

Westborough is mainly located in the Concord Basin (CB) with only approximately two percent of the town area located in the Blackstone Basin. Westborough had a population of 18,272 in 2010 with WDPW meeting the drinking water needs of entire town (U.S. Census 2010, WDPW 2014). WDPW withdraws water from the Concord Basin in the Chauncy, SuAsCo, Jackstraw, and Sandra Pond subbasins (Exhibit 1). WDPW is the only authorized entity withdrawing from, or discharging to, these source subbasins.

7 BCs are a function of impervious cover, cumulative groundwater withdrawal as a portion of the unimpacted August median flow, stream channel slope, and percent wetland within the stream buffer area. GWCs are based on the ratio of the 2000-2004 groundwater withdrawal volume to the unimpacted August median flow. The scale is from 1 (least impacted) to 5 (most impacted).

Exhibit 1: Town of Westborough, MA, WMA Subbasins, CFRs and WDPW's Water Sources



1.2.1 Demand and Supplies

WDPW serves primarily residential customers (50 percent of total water sales in 2010-2014) with a notable volume (26 percent) of commercial and industrial sales (Exhibit 2). During the 2010-2014 period, a significant amount of pumped water was unaccounted for water (UAW), which represents water that may be lost due to leakage from pipes, unmetered usage, or metering inaccuracies.

Exhibit 2: WDPW Customer Profile based on Average Water Sales in 2010 through 2014

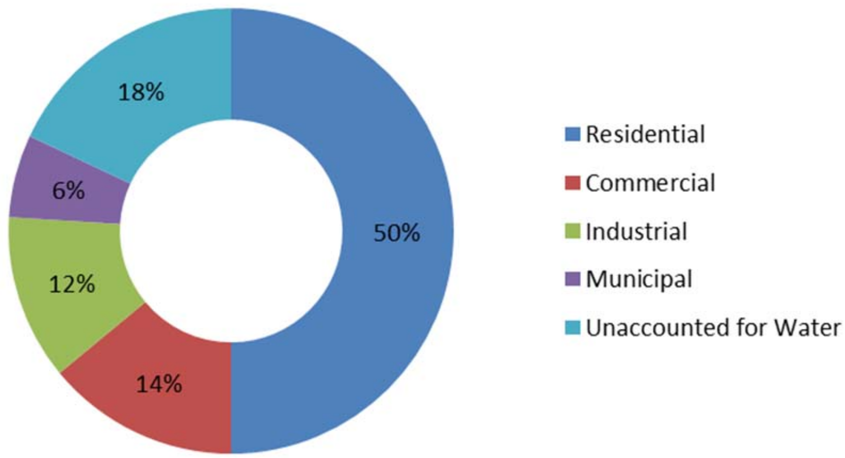


Exhibit 3 shows the average demand by month for 2000-2004 (the baseline period for the Regulations) and 2010-2014 (most recent years). The recent average annual demand in 2010-2014 was 2.07 MGD, which was a marked decrease from the baseline period. Comparing among months, WDPW customers use 18 percent more water in the summer, or approximately 0.4 MGD.[8] WDPW has been implementing mandatory outdoor water use restrictions during the summer since 2009. These restrictions are triggered by low streamflow in the basin as defined by the WMA permit. The restrictions limit watering to between 5 PM and 9 AM, and ban lawn irrigation or washing of vehicles, buildings, walkways or parking lots. Currently, WDPW does not have other town-wide demand management programs.

[8] We calculated winter demand as the average of demand in December through February and summer demand as the average of demand in June through August.

Exhibit 3: WDPW Average Monthly Demand during 2000-2004 and 2010-2014 Periods

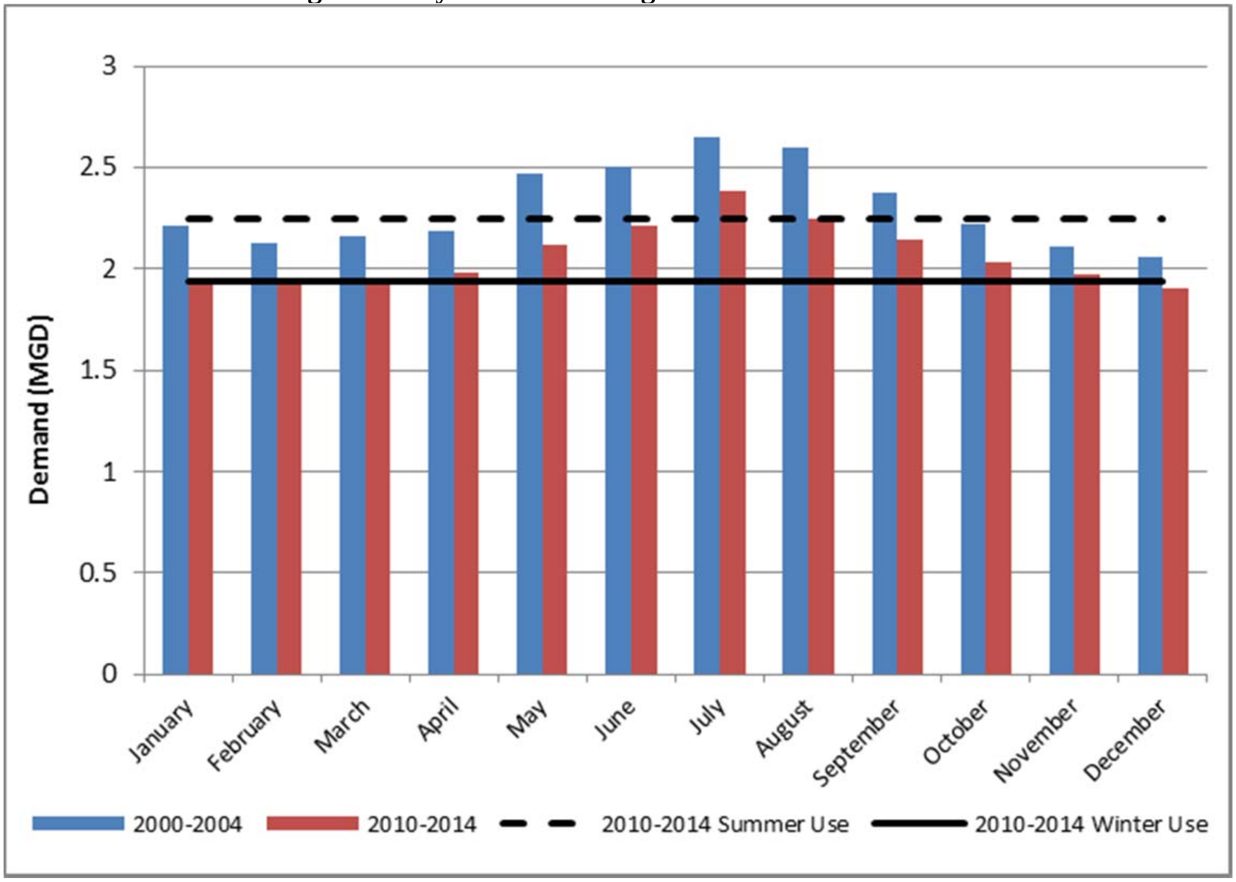


Exhibit 4 presents WDPW's withdrawal sources, their subbasin location, permitted or registered status, authorized daily pumping limits, and recent pumping rate. Sources in the Jackstraw and Sandra Pond subbasins are entirely registered; therefore, these subbasins are not regulated under the WMA. The Otis Street well is a registered source located in the SuAsCo subbasin with permitted sources; therefore, the SuAsCo subbasin is subject to the Regulations. Chauncy subbasin has two permitted wells, so this subbasin is also subject to the Regulations. WDPW's registered volume is 1.92 MGD. This registered volume may be withdrawn from either registered or permitted sources. WDPW has 1.18 MGD of permitted volume and may only withdraw that volume from permitted sources.

Exhibit 4: WDPW Withdrawal Sources and Pumping Limits

Subbasin ID	Subbasin Name	Source Name	Permitted / Registered	Authorized Pumping (MGD)	2014 Average Pumping (MGD)
12010	Chauncy	Chauncy Lake #1	Permitted	0.50	0.01
		Chauncy Lake #2	Permitted	0.79	0.02
12020	SuAsCo	Andrews I and IR	Permitted	0.58	0.40
		Andrews II	Permitted	0.55	0.22
		Otis St.	Registered	0.84	0.36
		Wilkinson	Permitted	0.29	0.15
		Indian Meadows	Permitted	1.13	0.00

Exhibit 4: WDPW Withdrawal Sources and Pumping Limits					
Subbasin ID	**Subbasin Name**	**Source Name**	**Permitted / Registered**	**Authorized Pumping (MGD)**	**2014 Average Pumping (MGD)**
12026	Jackstraw	Hopkinton St	Registered	0.55	0.19
		Morse St	Registered	0.40	0.15
12027	Sandra Pond	Sandra Pond (Westborough Reservoir)	Registered	1.00	0.69

The geographical location and aquifer characteristics of each withdrawal source affect the hydrological connection of the well to the stream or reservoir. Wells that are close to surface waterbodies may induce infiltration from those surface waters. Exhibit 5 shows relevant well and aquifer characteristics for each source. All wells except for Indian Meadows are relatively close to a surface water body and withdraw from unconfined aquifers.

Exhibit 5: Aquifer Characteristics of Withdrawal Sources (Northeast Geoscience 2015)					
Source Name	**Distance to Surface Waterbody (feet)**	**Name of Surface Waterbody**	**Percent Induced Infiltration**	**Aquifer Type**	**Transmissivity (ft^2/day)**
Chauncy Lake #1	35	Chauncy Lake	50%	Unconfined	6484
Chauncy Lake #2	10	Chauncy Lake	40%	Unconfined	6484
Andrews I	170	SuAsCo Reservoir	40%	Unconfined	20,614
Andrews II	35	SuAsCo Reservoir	100%	Unconfined	20,614
Otis St.	55	Assabet River Tributary	20%	Unconfined	11,200
Wilkinson	143	SuAsCo Reservoir	40%	Unconfined	4,011
Indian Meadows	812	Assabet River	20%	Confined	7,448
Andrews IR	175	SuAsCo Reservoir	40%	Unconfined	20,614
Hopkinton St	25	Jackstraw Brook	60%	Unconfined	7,900
Morse St	36	Jackstraw Brook	60%	Unconfined	7,900
Sandra Pond (Westborough Reservoir)	0	Sandra Pond	NA	NA	NA

Exhibit **6** shows the contribution of the withdrawals in each subbasin to Westborough's demand by month. The SuAsCo subbasin supplies 45 percent of WDPW demand on average, making it the most pumped subbasin. The other two groundwater-pumped subbasins, Chauncy and Jackstraw, supply 16 percent and 12 percent of WDPW demand, respectively. Sandra Pond (Westborough Reservoir) is the only WDPW surface water source. The Sandra subbasin contributes 31 percent of WDPW demand.

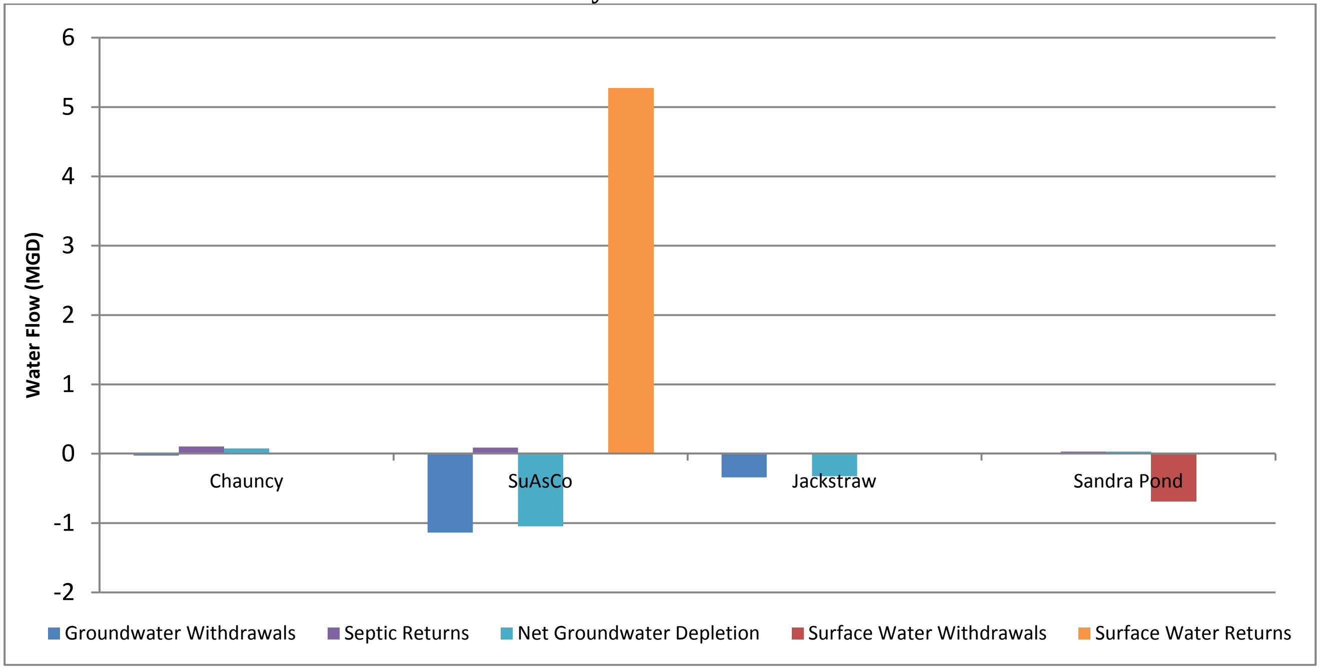
Exhibit 6: WDPW average daily pumping by month during 2010-2014

Month	Average Pumping Volume 2010-2014 (MGD)					Subbasin Share of Demand (%)			
	Chauncy (12010)	SuAsCo (12020)	Jackstraw (12026)	Sandra Pond (12027)	Total for WDPW	Chauncy (12010)	SuAsCo (12020)	Jackstraw (12026)	Sandra Pond (12027)
January	0.265	0.812	0.235	0.807	2.120	13%	38%	11%	38%
February	0.275	0.782	0.290	0.737	2.084	13%	38%	14%	35%
March	0.291	0.716	0.225	0.585	1.818	16%	39%	12%	32%
April	0.143	0.749	0.237	0.972	2.101	7%	36%	11%	46%
May	0.173	0.818	0.292	0.992	2.275	8%	36%	13%	44%
June	0.164	0.762	0.330	0.978	2.233	7%	34%	15%	44%
July	0.212	0.891	0.354	0.869	2.326	9%	38%	15%	37%
August	0.183	0.986	0.332	0.798	2.300	8%	43%	14%	35%
September	0.159	0.988	0.258	0.822	2.226	7%	44%	12%	37%
October	0.144	0.867	0.271	0.766	2.048	7%	42%	13%	37%
November	0.148	0.861	0.284	0.697	1.990	7%	43%	14%	35%
December	0.212	0.839	0.226	0.649	1.927	11%	44%	12%	34%

Note: This table includes both groundwater and surface water pumping by WDPW.

Withdrawal and return flows in each source subbasin are shown in Exhibit 7. Westborough is the only authorized entity for withdrawals and discharges; therefore, all flows in the exhibit represent Westborough flows. Approximately 90 percent of the town is sewered and served by the Westbrough Wastewater Treatment Plant (WWTP). The WWTP is located in the SuAsCo subbasin and discharges to the Assabet River in that subbasin. The WWTP also receives wastewater from Town of Shrewsbury (Shrewsbury) and the Town of Hopkinton (Hopkinton) with an average discharge of 5.3 MGD. Although the SuAsCo subbasin supplies the largest share of water for Westborough, it is a surcharged subbasin as identified in Appendix B of the WMA Permit Guidance document (MassDEP, 2014).

Exhibit 7: WDPW Withdrawals and Returns by Subbasin



1.2.2 Treatment Plants and Distribution System

WDPW has two primary water treatment plants (WTPs) and approximately 130 miles of main that connect all sources and customers (Exhibit 8). The Westborough Water Purification Facility (Fisher street plant) has a capacity of 3.5 MGD and the green sand treatment plant (Oak street plant) has a capacity of 1 MGD. Some wells have minimal treatment at the pumping site and connect directly to the distribution system. Exhibit 8 shows all treatment capacities and connections between treatment plants and sources.

Exhibit 8: Water Infrastructure Assets

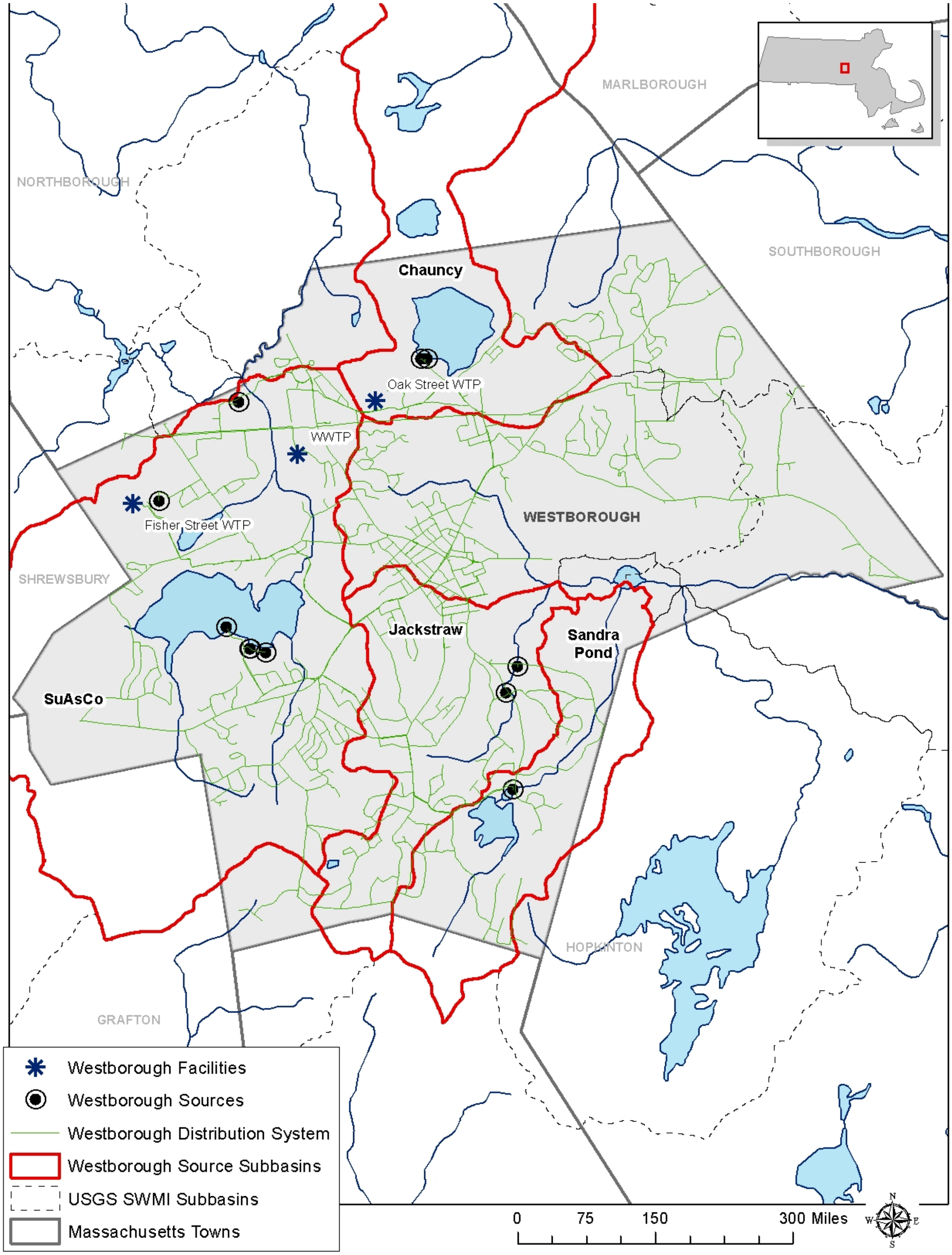


Exhibit 9: WDPW Water Treatment Locations			
Treatment Locations	**Wells Treated**	**Treatment Capacity (MGD)**	**Subbasin**
Westborough Water Purification Facility	Andrews I Well	3.5	SuAsCo
	Andrews II Well		
	Wilkinson Well		
	Andrews Well R1		
	Sandra Pond (Westborough Reservoir)		
Oak Street Water Treatment Plant	Chauncy Lake Well #1	1.008	SuAsCo
	Chauncy Lake Well #2		
	Indian Meadows Well		
Otis St. Well	Otis St. Well	0.84	Otis
Hopkinton Road Well	Hopkinton Rd. Well	0.55	Jackstraw
Morse Street	Morse St. Well	0.40	Jackstraw

The existing treatment plants and distribution system limit the flexibility of pumping operations. Two main challenges exist. First, WDPW must use the Hopkinton and Morse Street wells at specific rates to properly distribute chlorine and maintain pressure in that section of town. This is especially challenging during the summer months.

Second, the existing connections and water quality considerations limit which sources may be pumped at a given time. The Andrews I, Andrews IR, Andrews II, and Wilkinson wells (Andrews well field) and Sandra Pond/Westborough Reservoir feed the Fisher street plant. This plant requires a minimum flow to operate properly; therefore, WDPW must pump these sources at varying rates to meet that overall minimum rate for the plant.

The Oak street plant is connected to the Chauncy and Indian Meadows wells. However, the Indian Meadows well water is high in iron and manganese and the Oak street plant can no longer treat this source sufficiently. WDPW has not used the Indian Meadows well since 2011. Therefore, the Oak street plant is only online occasionally when the Chauncy wells are pumped.

Near-term changes and upgrades to the system are planned which would remove these limitations and provide pumping flexibility among source subbasin. These changes include:

- Connecting an Otis Street Replacement Well and the Indian Meadows well to the Fisher street plant;
- Building sufficient treatment at the Chauncy wells to connect them directly to the system; and
- Adding replacement wells at the Wilkinson Well and other locations to maintain authorized yield.

In this study, we assume no limitations on pumping allocation among sources except for the authorized volume of each source.

2 Analysis of Cost-Effective Management Actions

MassDEP initiated the permit renewal process for WDPW in May 2015 with a basin-wide outreach meeting. WDPW must submit their permit renewal application with minimization and mitigation plans, if any, by August 31, 2015. As summarized in Section 1.1, the revised Regulations require permittees to meet standard permitting conditions, minimize existing impacts in depleted basins and CFRs, and mitigate withdrawals above baseline allocation.

In this section, we first compare data from MassDEP for the baseline period of 2000-2004 with more recent data from WDPW. We provide a general overview for each subbasin and highlight potential changes in requirements from a data refinement submission. In the remaining subsections, we then review the relevant WMA requirements for each subbasin. We assess cost-effective options for meeting the requirements in order to inform Westborough's planning for the permit renewal application.

2.1 Data Refinement

2.1.1 Baseline Conditions

Exhibit 10 provides an overview of each source subbasin for the regulatory baseline period of 2000-2004 as compiled by MassDEP.[9]

Exhibit 10: WMA Baseline August Conditions, 2000-2004 (Source: WMA Tool)

Subbasin Name	Registered / Permitted	ANGD (%)	CFR	Surcharged[10]	Groundwater Category (GWC)	Biological Category (BC)
Chauncy	Permitted	42.9	No	No	4	5
SuAsCo	Both	59.5	Yes	Yes	5	5
Jackstraw	Registered	55.3	Yes	No	5	5
Sandra Pond	Registered	-15.2	Yes	No	2	4
Subbasin Name	**August Unaffected Streamflow (MGD)**	**August Affected Streamflow (MGD)**	**August Groundwater Withdrawals (MGD)**	**August Groundwater Recharge (MGD)**	**To Change GWC (MGD)**	**To Change BC (MGD)**
Chauncy	0.805	0.460	0.423	0.078	0.019	0/ NA
SuAsCo	1.671	4.939	1.084	0.091	0 / NA	0/ NA
Jackstraw	0.463	0.207	0.331	0.075	0 / NA	0/ NA
Sandra Pond	0.436	0.501	0.013	0.079	0.030	0.0306

The calculation of the ANGD for WMA baseline August Conditions in this report is slightly lower than the ANGD values calculated by MassDEP because MassDEP uses the USGS conversion factor to convert from cfs to mgd. The USGS conversion factor is 1 cfs = 0.645 mgd, whereas we calculated the conversion factor to be 0.646 (Conversation with Richard Friend at MassDEP, 2015).

9 Data sources include USGS dataset from the Massachusetts Water Indicators (MWI) report data and Sustainable Yield Estimator (SYE) as compiled in the WMA tool. The majority of the data focus on conditions in August during the baseline period of 2000-2004.

10 The Guidance lists all subbasins that are considered surcharged. These subbasins are significantly surcharged and qualify for wastewater offsets as discussed later in the report.

These data indicate the following overview for each subbasin:

- Subbasin 12010 (Chauncy): This subbasin has two permitted groundwater wells located adjacent to Chauncy Lake. This subbasin is a GWC 4, August net groundwater depleted and the only source subbasin that does not have a CFR.

- Subbasin 12020 (SuAsCo): This subbasin has six groundwater wells; four adjacent to SuAsCo reservoir and two downstream of the reservoir. Otis well, downstream of the reservoir, is a registered source. The subbasin is GWC 5, August net groundwater depleted and contains two CFR streams. The WWTP discharges to the Assabet River in this subbasin downstream of the reservoir with an average discharge of 5.3 MGD and a permitted average monthly limit of 7.68 MGD.[11] As such, this subbasin is also surcharged as noted in Appendix B of the WMA Permit Guidance (MassDEP, 2014). Although the river is surcharged, the tributary streams are depleted.

- Subbasin 12026 (Jackstraw): The two groundwater wells in the subbasin are located adjacent to the stream, which is a CFR. This subbasin is a GWC 5, August net groundwater depleted and feeds into Cedar Swamp, an Area of Critical Environmental Concern (ACEC).[12] However, both sources are registered withdrawals and WMA requirements to do not apply to this subbasin and its sources.

- Subbasin 12027 (Sandra Pond): The Westborough Reservoir/Sandra Pond is the town's only surface water source. This subbasin is GWC 2, net August groundwater surcharged, contains a CFR (Piccadilly Brook) and feeds into Cedar Swamp. Sandra Pond is a registered source and WMA requirements do not apply to this subbasin.

2.1.2 Conditions in 2010-2014

Significant changes have occurred between the baseline period and 2010-2014. WDPW decreased its demand and shifted its pumping regime. Exhibit 11 shows the change in average annual pumping in each subbasin between the baseline and 2010-2014. Overall, WDPW reduced demand by 0.25 MGD and shifted two-thirds of the water pumped in Chauncy subbasin to the Jackstraw and Sandra Pond subbasins.

Exhibit 11 Pumping Regime Alterations from 2000-2004 to 2010-2014

Subbasin	2000-2004 Period		2010-2014 Period	
	Average Annual Pumping (MGY)	Percent Demand Met by Basin (%)	Average Annual Pumping (MGY)	Percent Demand Met by Basin (%)
Chauncy	126	15	41	5
SuAsCo	346	42	324	42

11 Authorized discharge limit for Westborough WWTP determined by National Pollutant Discharge Elimination System (NPDES) Permit MA0100412.

12 Cedar Swamp was the first Area of Critical Environmental Concern designated in Massachusetts. The approximately 1650 acres are primarily vegetated wetlands, providing critical flood water storage capacity for the Sudbury River basin and baseflow to the Sudbury River which experiences seasonal low flows. The area is the headwaters of the Sudbury River and overlays the medium- and high-yield aquifers that supply two public wells for Westborough. http://www.mass.gov/eea/agencies/dcr/conservation/ecology-acec/cedar-swamp.html

Exhibit 11 Pumping Regime Alterations from 2000-2004 to 2010-2014				
Subbasin	**2000-2004 Period**		**2010-2014 Period**	
	Average Annual Pumping (MGY)	**Percent Demand Met by Basin (%)**	**Average Annual Pumping (MGY)**	**Percent Demand Met by Basin (%)**
Jackstraw	101	12	109	14
Sandra Pond	252	31	303	39

In addition AstraZeneca Pharmaceuticals (AstraZeneca) is relocating outside of Westborough as of 2015. In 2013, AstraZeneca used 0.135 MGD of water supplied by Westborough; therefore a reduction of the same magnitude is expected this year and potentially beyond depending on the water use of the commercial or industrial entity which will be replacing AstraZeneca. The net effect of these changes is shown in Exhibit 12 below. Changes material to WMA requirements are highlighted in blue. The blue values are improvements in environmental conditions from the baseline conditions previously shown in Exhibit 10. The WMA guidance does not provide the formula for calculating a revised BC nor does it provide the increased withdrawals that change the BC for subbasins; therefore, these metrics are not shown in Exhibit 12.

Exhibit 12: 2010-2014 August Conditions							
Subbasin Name	**Registered / Permitted**	**AGND (%)**	**CFR**	**Surcharged**	**August Groundwater Withdrawals (mgd)**	**GWC**	**To Change GWC (mgd)**
Chauncy	Permitted	2.3	No	No	0.097	3	0.104
SuAsCo	Both	53.9	Yes	Yes	0.992	5	0
Jackstraw	Registered	57.7	Yes	No	0.342	5	0
Sandra Pond	Registered	-15.2	Yes	No	0.013	1	6.6×10^{-5}

Note: Shading indicates changes from Exhibit 10. Sandra Pond is only surface water withdrawals; therefore, the August groundwater withdrawals did not change. Sandra Pond showed an improved GWC due to the updated conversion factor used to calculate the GWC.[13]

These data refinements may be submitted to MassDEP per WMA Permit Guidance Document Section 10 (MassDEP, 2014). If MassDEP accepts the refinements, the most notable effect will be the removal of minimization requirements for Chauncy subbasin, which would have an adjusted AGND below 25%.

2.2 Standard Permitting Conditions

Exhibit 13 summarizes standard permit conditions and WDPW's status with respect to each condition. WDPW will need to address or modify the following to be in compliance with the new permit:

13 The conversion factor update is a result of the difference in conversion factor used to calculate GWC. USGS determined the GWC for the Regulations using a slightly lower conversion factor than the conversion factor that was used in this report (0.645 compared to 0.646).

- Unaccounted for water (UAW): Conduct a water audit and full leak detection to determine the cause of the high UAW (*i.e.*, due to real losses or apparent losses); Based on results of the audit, calibrate or replace meters or repair leaks.

- Outdoor water use: Prepare for logistics of new requirements and distribute educational material to customers to ensure compliance.

Exhibit 13: Standard Conditions for Water Withdrawal Permits

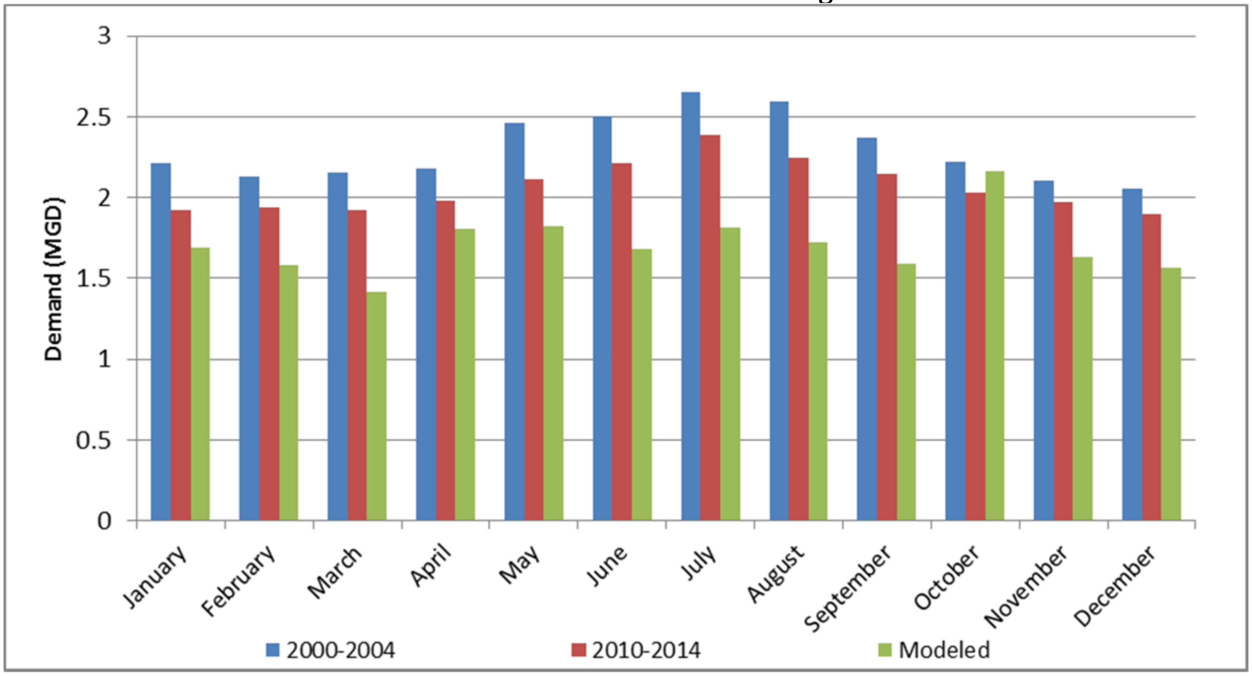
Condition[1]	Status[2]
Performance standards	
65 residential gallons per capita per day (RGPCD)	57 RGPCD
10 percent unaccounted-for-water	14 percent UAW
Water conservation requirements	
System water audits and leak detection	Leak detection of half the town each year
Metering	Full metering as well as meter replacement program tied to the Building Permit review process
Pricing	Tiered pricing
Residential and public sector conservation	Moratorium on connecting automated sprinkler systems to the municipal water system
Industrial and commercial water conservation	Moratorium on connecting automated sprinkler systems to the municipal water system
Lawn and landscape	See "Limits on nonessential outdoor water use below"
Education and outreach	Provide information on water conservation in the CCR report distributed to all residents by postal delivery each year. Provide information on stormwater and water conservation at a table during Town Meeting each year.
Limits on nonessential outdoor water use	
Standard outdoor water use restrictions	-Existing: Restricted hours May-September -Under new permit: maintain restricted hours and reduce to 2 days per week all season and 1 day per week if streamflow below trigger

(1) Conditions as described in *Water Management Act Permit Guidance Document* (MassDEP 2014)

(2) WDPW status based on WDPW's 2014 Annual Statistical Report to MassDEP and WDPW personal communication

Exhibit 14 shows the estimated decline in average annual and summer demand if all standard permit conditions are met (shown as the "modeled" demand in the chart). Historically, WDPW's UAW has exceeded 10 percent, the maximum percentage allowed by the WMA permit (Exhibit 2). To estimate the modeled demand, we assume that WDPW will meet the 10 percent limit and have adjusted the future demand to reflect reductions in UAW. We also adjusted demand to reflect a 15 percent reduction in demand for the summer months (May through September); this is the reduction that may be expected from implementing two-day outdoor watering restrictions. Finally, we removed 0.135 MGD of demand from WDPW's historical pumping record to account for the decrease in demand as a result of AstraZeneca relocating. We use these demand values for determining minimization and mitigation needs.

Exhibit 14: WDPW Demand Modeled Under Standard Permitting Conditions

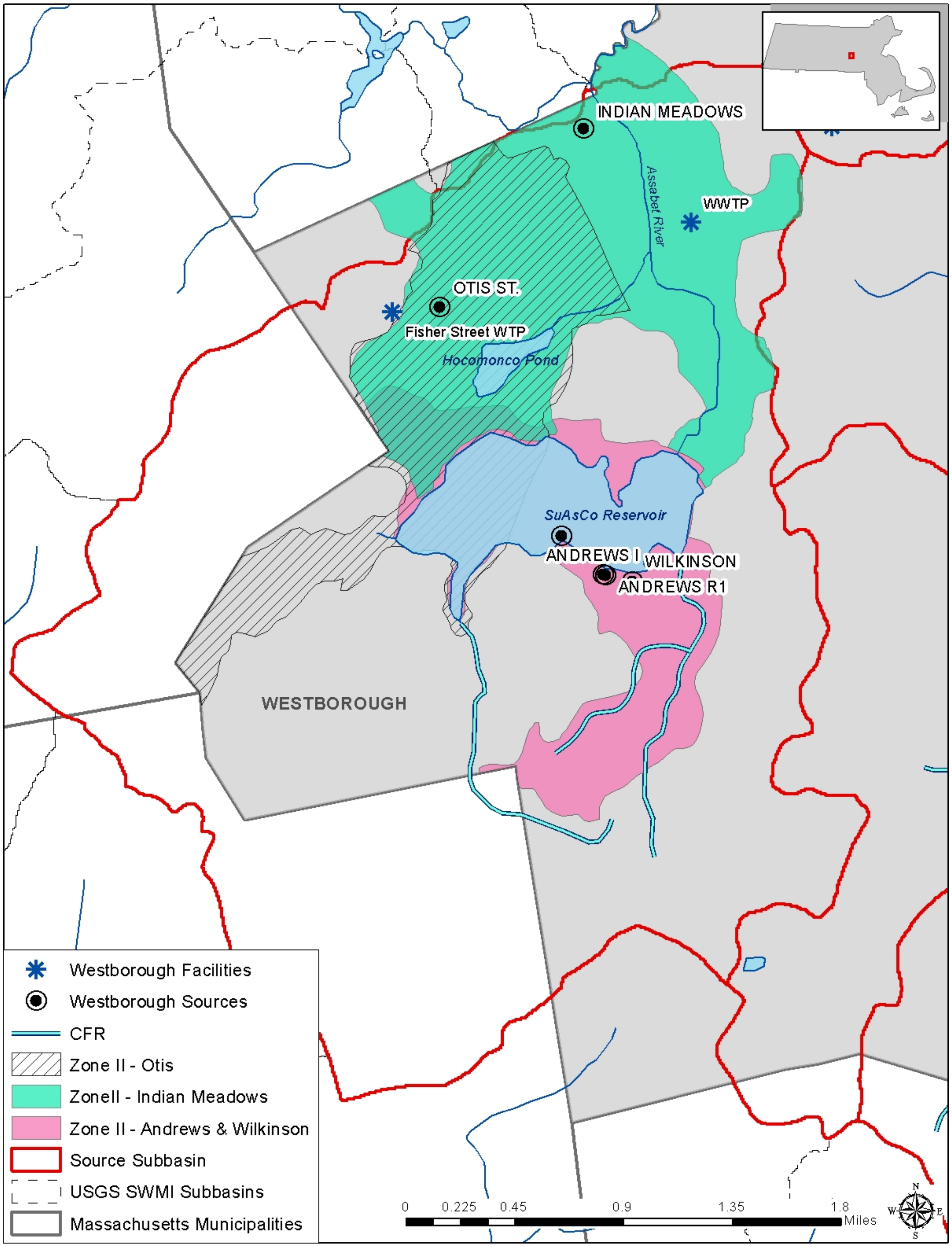


2.3 Coldwater Fishery Resource

Coldwater Fishery Resources (CFRs) require specific consideration as part of the WMA permitting process. As temperature-dependent habitats, CFRs are strongly influenced by groundwater and particularly vulnerable to impacts from groundwater withdrawals and other anthropogenic impacts. CFRs are designated by the state based on water temperature or the presence of cold water-dependent fish. Therefore, the Regulations require all permittees with a CFR in any of their permitted subbasins to conduct a desktop optimization, focusing specifically on reducing impacts to the CFRs (MassDEP, 2014).

Westborough has three source subbasins identified as containing CFRs – Jackstraw (Jackstraw Brook), Sandra (Piccadilly Brook), and SuAsCo (two unnamed tributaries). The Jackstraw and Sandra subbasins only have resisgstered sources; therefore, they are not regulated under the WMA. Initial screening of the SuAsCo subbasin based on Zone II Wellhead Protection Areas suggests that the two unnamed CFR streams are upstream of the SuAsCo reservoir—shown as two streams south of the reservoir in Exhibit 15. One CFR overlaps with the Zone II delineation for the well field at the SuAsCo reservoir, which includes three Andrews wells and one Wilkinson well. The WMA guidance states that a desktop pumping optimization analysis is the required action for subbasins with CFRs (MassDEP, 2014). In Section 2.4.2 of this report, we assess the potential for shifting pumping to other subbasins as part of meeting the minimization requirements.

Exhibit 15: Zone II Wellhead Protection Areas for WDPW Wells in SuAsCo Subbasin



2.4 SuAsCo Minimization

The SuAsCo subbasin requires actions to minimize the existing impacts of withdrawals. The WMA guidance does not specify methods for calculating minimization credits for some actions nor the extent of required action. The extent of the minimization that is required is stated as "to the greatest extent feasible." For the purpose of this planning study, we evaluated three options: wastewater discharge, re-allocating pumping to other source subbasins, and surface water releases. Consultation with MassDEP will be necessary to determine final requirements in order for WDPW to prepare its minimization plan.

2.4.1 Wastewater Discharge

Under Section 6 of the Guidance, minimization may include returns of water including "wastewater discharges that result in improvements to the quantity and timing of streamflow." The WWTP in the SuAsCo subbasin discharges in excess of the withdrawals in the subbasin; therefore, the subbasin is surcharged as noted in Appendix B of the WMA guidance. However, this surcharge only affects the Assabet River mainstem where the WWTP discharge is located. The discharge does not improve conditions of the Assabet tributaries. Two uncertainties affect the determination of minimization credit for this wastewater return: the location criteria and the method for calculating minimization credit.

Regarding location, the WMA guidance states that "potential returns should be evaluated in the following order: to the same subbasin, same major basin, and finally another major basin." (MassDEP, 2014) The guidance does not discuss requirements regarding the location of the wastewater discharge within a subbasin. Accordingly, the WWTP discharge may be interpreted as an applicable minimization action for all wells in SuAsCo subbasin.

However, the WMA guidance does discuss "offset adjustments" for surcharged streams in the context of the mitigation requirements, and specifies that wells must be hydrologically connected to the surcharged stream reach. The guidance states that "if a well's wellhead protection area (Zone II) includes a portion of the surcharged stream reach, it is presumed that the well is hydrologically connected." (MassDEP, 2014) An alternate interpretation of the guidance is that the same (mitigation) conditions would apply to minimization.

If minimization is subject to the same requirement as mitigation, then the Zone II Wellhead Protection Areas for each well presented in Exhibit 15 show that only Indian Meadow well qualifies. The well has a total authorized volume of 1.13 MGD and has not been pumped recently (Exhibit 4); therefore this well could accommodate additional pumping to make up for reductions from other wells. The Indian Meadows well has not been used since 2011 due to water quality issues but if it were connected to the Fisher treatment plant as discussed in Section 1.2.2, the well could provide a cost-effective solution for minimization.

Regarding the extent of credit, the WMA guidance does not specify the method for calculating the potential credit for wastewater returns for minimization; it provides these calculations only for mitigation. For mitigation, the guidance specifies the "surcharge offset adjustment to be the lesser of a) the applicant's withdrawal above baseline; or b) the amount of surcharge in the subbasin for August, less a 1 MGD buffer." (MassDEP, 2014) For minimization, the relevant part of this method is the concept of a 1 MGD buffer. The WMA tool indicates that the average August discharge during the baseline period for

WWTP was 4.4 MGD.[14] Subtracting the buffer potentially provides a 3.4 MGD return for minimization of existing withdrawals. As Exhibit 16 shows, the average withdrawals in SuAsCo are 0.887 MGD on average and 1 MGD in the late summer bioperiod, which is substantially less than the wastewater return volume.

Exhibit 16: 2010-2014 Withdrawals from Wells in SuAsCo Subbasin		
Well	**Annual (MGD)**	**Late Summer Bioperiod (MGD)**
Andrews I	0.094	0.099
Andrews II	0.178	0.205
Andrews R1	0.139	0.275
Wilkinson	0.241	0.141
Otis	0.198	0.269
Indian Meadows	0.037	0.011

Consultation with MassDEP is necessary to determine whether the wastewater discharge meets minimization requirements for the SuAsCo subbasin or if additional actions are necessary. Given this uncertainty, we evaluated two other potential actions for minimization that may be needed in addition to the wastewater discharge.

2.4.2 Source Optimization

As an additional minimization option, we assessed WDPW's ability to shift pumping to other subbasins. The Jackstraw and Sandra subbasins are registered withdrawals and not subject to WMA requirements. Recent pumping in these subbasins was approximately 1.03 MGD. Otis well in the SuAsCo subbasin is also a registered source and its pumping combined with Jackstraw and Sandra subbasins cannot exceed 1.92 MGD, the total registered withdrawal volume. During the 2010-2014 period, WDPW pumped Otis well at 0.36 MGD for a total registered withdrawal of 1.30 MGD. This pumping configuration, Option 1, provides 0.53 MGD of withdrawals available in the registered Jackstraw and Sandra subbasins as shown in Exhibit 17. If WDPW shifts any pumping from the Otis well, then pumping available in the registered subbasins increases. In this situation, Option 2, the total pumping that could be shifted from SuAsCo is 0.89 MGD which exceeds its annual and late summer bioperiod pumping.

Exhibit 17. Withdrawal Volumes for Registered Wells in MGD		
Pumping Pattern	**2010-2014**	**No Otis**
Jackstraw	0.34	0.34
Sandra	0.69	0.69
Otis	0.36	0.00
Registered Pumped	*1.39*	*1.03*
Registered Limit	*1.92*	*1.92*
Remaining Registered	**0.53**	**0.89**

14 2010-2014 average August discharge was not readily available for this report but should be obtained for the permit renewal application.

Exhibit 18. Pumping Distribution among SuAsCo Subbasin Wells during 2010-2014		
Well Group	**Annual (MGD)**	**Late Summer Bioperiod (MGD)**
Andrews well field	0.651	0.721
Otis	0.198	0.269
Indian Meadows	0.037	0.011
Jackstraw wells	0.299	0.320
Sandra Pond	0.830	0.859

Note: Indian Meadows shows minimal pumping because it has not been pumped since 2011 due to water quality.

Shifting withdrawals to the registered subbasin would not require minimization in those subbasins since they are exempt from the Regulations. If wastewater and surface water releases are not sufficient and/or feasible for minimization, this would be another least-cost option for WDPW. However, both of the registered subbasins are CFRs and feed Cedar Swamp. Given the potential environmental impacts of additional withdrawals from these subbasins, MassDEP, OARS and other stakeholder may wish to discuss reallocating some of the *registered* withdrawal volume to the Chauncy subbasin instead without creating requirements for WDWP action in that subbasin.

Under the scenario that reallocation of withdrawals in Chauncy requires actions to minimize impacts, it may be possible to use surface water releases from Lake Chauncy to offset impacts in that subbasin. We discuss this option for the Chauncy subbasin in Section 2.7.2.

2.4.3 Surface Water Releases in SuAsCo and WMOST Cost-Effectiveness Analysis for Minimization of Impacts

Wastewater discharge and source optimization in the previous sections could be assessed without modeling. In case those options are not sufficient to meet the WMA minimization requirements, we also considered additional options using WMOST to determine the most cost-effective combination of actions. Appendix A provides details on the setup of WMOST models including input data and validation/calibration runs. Options that we considered in the model include:

- Stormwater retrofit and redevelopment for recharge credit;
- Interbasin transfer:
  - Connecting to the Massachusetts Water Resources Authority (MWRA) (MWRA currently continues to supply water to the former Westborough State Hospital but has significant initial fees for joining and there would be costs to upgrade interconnection infrastructure);
  - Approaching Northborough to request the use of its wells (Northborough has joined the MWRA and no longer uses their wells. These wells have water quality issues that must be considered and addressed);

- Surface water releases from the SuAsCo reservoir:[15] Approach Massachusetts Department of Conservation and Recreation (DCR) to discuss installing streamflow controls and managing outflows for meeting streamflow targets;
- Indirect and direct water reuse; and
- Aquifer storage and recharge.

The model covered the watershed of the SuAsCo reservoir, including wells adjacent to the reservoir. Downstream wells were not included. Decentralized wastewater recharge was not included in the modeling. We set streamflow targets for the late summer bioperiod at the GWC 3 level which is slightly higher (*i.e.*, more environmentally protective) than 25% ANGD,[16] the metric for requiring minimization. Calculation of the streamflow targets are detailed in Appendix A. For months outside the late summer bioperiod (October through June), we specified the minimum streamflow targets from the validation/calibration run to ensure that flows in other months are not degraded in order to meet the late summer bioperiod targets.

Modeling results indicate that a maximum storage capacity of 5.47 MG is required to meet streamflow targets. The modeled reservoir volume in Exhibit 19 shows a dry period during August 2001 when the storage of water was required on some days to meet streamflow release needs on other days. The maximum storage volume is approximately 0.1 percent of the reservoir's permanent pool which is 5,000 MG. The storage volume for flood protection is 10,000 MG. Therefore, it is not likely that controlling approximately 6 MG of the storage volume would adversely affect the other purposes of the dam. However, consultation with DCR will be necessary to request authority and to discuss technical and logistical consideration.

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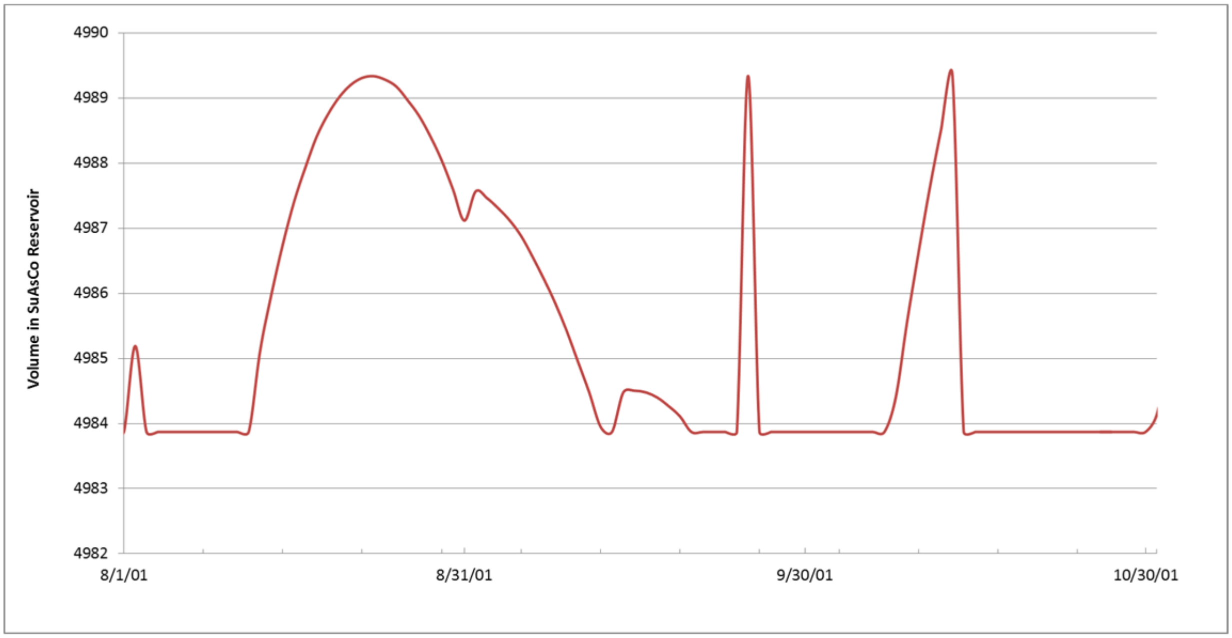
15 The SuAsCo reservoir is also known as the A-1 reservoir created by the George H. Nichols Dam, built in 1970. The Department of Conservation and Recreation (DCR) owns the site and the Natural Resources Conservation Service (NRCS) designed and partially funded the project. The purpose of the dam is flood protection, recreation, fish and wildlife and water supply (Lyons 2015). The reservoir is not actively managed and its water level is controlled by the principal spillway crest elevation. Based on information from NRCS, we also understand that if the impoundment water level drops significantly below the permanent pool level (principal spillway crest), there may be a negative impact on Westborough's well field, the only other existing water supply for the golf course located on the east side of Mill Road, recreation, wildlife habitat and adjacent wetlands.

16 The targets are similar due to the same 25% threshold for withdrawals to streamflow and minimal septic or groundwater return flows considered in ANGD that would otherwise differentiate the two metrics.

Exhibit 19. Modeled Volume for the SuAsCo Reservoir



Note: The reservoir volume is generally stable; fluctuations shown here are the storage and release of volume needed to meet streamflow targets.

2.5 Projected Water Needs and Mitigation

MassDEP allocated 2.30 MGD to WDPW as baseline withdrawal.[17] In the past five years, WDPW's average withdrawal levels were near this baseline, ranging from 1.99 to 2.23 MGD. Several measures are available, and some required, that may keep demand below 2.30 MGD in the near future including the standard conditions discussed in Section 2.2 and initiating a water efficiency program. Demand management or water efficiency is required before withdrawals above baseline and commensurate mitigation is allowed.

In Exhibit 20, we summarize the demand reduction that is expected from meeting the standard conditions and initiating a water efficiency program over the first years of the permit, prior to permit review. Negotiating with developers for "smart" and "efficient" development will be critical to managing future demand. This may include requirements for the installation of high-efficiency water fixtures and appliances as well as stormwater management beyond on-site requirements (*i.e.*, retrofit of existing impervious area). WDPW already encourages and oversee stormwater retrofit and redevelopment projects. Projects since 2005 should be identified, documented and quantified to determine applicable credit. On-going tracking and quantifying of credit should be conducted.

We investigated the potential impact and cost of a water conservation program that would be applicable for Westborough. At this time, the primary water conservation program enacted by WDPW is the mandatory nonessential summer outdoor use restrictions required by the WMA permit. WDPW also limits commercial underground irrigation systems connected to the town water system and has a rain barrel program for residents to purchase rain barrels for their homes.

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17 This volume is the town's water use in 2005 plus five percent.

While these conservation measures are helpful in reducing demand, the first requested action under the Regulations is to apply demand management best practices in the town. In order to fully comply with the Regulations, WDPW should consider implementing a 5-year water conservation program. Exhibit 20 shows five common water conservation measures, the cost of the programs assuming a 3-percent interest rate, and the expected annual water savings that may be accomplished over the 5-year planning horizon. We derived these estimates using the Water Efficiency Calculator developed under a separate SWMI Grant to the Town of Wrentham (Abt Associates, 2015).

Exhibit 20: Demand Reduction Programs

Measure Name	Consumer Type	Cost of Conservation Measure Program	Lost Revenue from Water Sales	Avoided Water Supply Cost	Net Cost	Annual Water Savings (MGD)	Annualized Net Cost per Water Savings ($/MG)
Showerhead retrofit kit	Residential	$1,900	$73,100	$28,500	$46,400	0.01	$3,100
Faucet aerator	Residential	$2,000	$10,900	$4,300	$8,700	0.001	$3,800
Ultra low flush toilets	Residential	$15,300	$176,600	$68,900	$123,000	0.02	$3,300
A/C condenser	Commercial / Business	$109,800	$512,300	$199,000	$423,000	0.064	$4,000
Total		**$129,000**	**$772,900**	**$300,700**	**$601,100**	**0.10**	**$14,200**
Annualized Cost over 5 Years		**$25,800**	**$154,580**	**$60,140**	**$120,220**	**--**	**$2,840**

The table lists example water conservation measures that WDPW could offer to town residents for free or as part of a rebate program. The cost of the conservation measure program in the table represents the total cost of the conservation measure program, including the fixed cost of implementing the program and the variable cost related to the number of units purchased. In order to alleviate the burden of the costs on WDPW, the conservation measures could be offered at a rebate price to customers, where WDPW pays half the cost and residents or businesses pay the other half.

The water savings and costs are calculated with the assumption that 33 percent of the town participates in the program by the end of the 5 years. The lost revenue is forgone water sales due to water savings, and the avoided water supply cost represents avoided pumping and water treatment expenses. The net cost to WDPW is the cost of the conservation program plus the lost revenue, less the avoided cost. The total net cost is less if we assume that WDPW will offer rebates instead of distributing the conservation measures to their water users (although doing so may decrease the level of participation and water savings). The annual cost to WDPW for the full price of the program (*i.e.*, no rebates given) is $120,220, which provides 0.1 MGD of water savings for an annual net cost of $2,840 per MGD saved.

For the longer term planning required for the 20-year permit renewal, WDPW may request to renew its previously authorized volume of 3.10 MGD. At this volume, WDPW will need to implement mitigation measures to offset 0.80 MGD. The WMA guidance specifies that demand management must be implemented to the greatest extent feasible prior to mitigation. As such, the above discussed water efficiency program should be developed, implemented and its success tracked since mitigation measures must be implemented prior to withdrawal above baseline. However, for the 20-year planning, we evaluate mitigation options so that a mitigation plan may be developed and submitted to MassDEP as part of the permit renewal application.

2.5.1 Surcharged Reach Offset Adjustment

As discussed in Section 2.4.1, the SuAsCo subbasin has significant discharge from a WWTP that receives wastewater from Westborough and two other towns. Following the WMA guidance for calculating the offset adjustment for mitigation, we determined a total offset of 2.4 MGD (Exhibit 21). These calculations are based on the 2000-2004 baseline period because the 2010-2014 average August WWTP discharge was not readily available for this report. WDPW should obtain and use more recent values of WWTP discharges for the permit renewal application. Baseline and more recent pumping in SuAsCo have not changed significantly and have ranged from 0.89 to 0.95 MGD (Exhibit 6).

The 2.4 MGD offset is significantly greater than the required 0.80 MGD mitigation. The Indian Meadows well, which is downstream of the wastewater discharge and whose Zone II overlaps with the WWTP (Exhibit 15), is eligible for the wastewater offset. The well has a total authorized volume of 1.13 MGD and has not been pumped recently (Exhibit 4). Depending on the extent to which this well is used to meet minimization requirements in the SuAsCo subbasin, there may be pumping volume remaining to meet the 0.80 MGD mitigation volume. As discussed before, Indian Meadows well has not been used since 2011 due to water quality issues but if it were connected to the Fisher treatment plant as discussed in Section 1.2.2, it could provide the most cost-effective solution for meeting future water needs beyond the baseline volume.

Exhibit 21: Surcharged Reach Offset Adjustment for SuAsCo

Surcharged Reach Offset Adjustment Calculation in MGD	2000-2004[18]
Average August Returns from WWTP	4.4
Average August Withdrawals	-1.0
1 MGD Buffer	-1.0
Surcharged Reach Offset Adjustment	**2.4**

2.5.2 Source Optimization

As discussed in the previous section, the Indian Meadows well has 1.13 MGD of unused capacity that is fully offset by the WWTP discharge. Connecting this well to the Fisher plant would provide mitigation volume beyond the estimated mitigation need. Depending on the extent to which WDPW uses this well to meet minimization requirements in the SuAsCo subbasins, pumping volume may remain for mitigation.

In addition, as discussed in Section 2.4.2, registered pumping volumes remain in the Jackstraw and Sandra subbasins. Maximizing withdrawals in those two subbasins would help meet WDPW minimization and/or mitigation requirements. However, as discussed, these subbasins are CFRs and feed Cedar Swamp. As alternatives to maximizing pumping in these two subbasins and SuAsCo, we also assessed options in the next sections that may provide better environmental outcomes. However, based on the WMA guidance and the information presented in the above sections, we expect that WDPW will not be compelled to actions beyond those already discussed; but WDPW may nonetheless be willing to

[18] 2010-2014 average August discharge was not readily available for this report but should be obtained for the permit renewal application.

discuss alternatives that provide better environmental outcomes without new/additional requirements at WDPW expense in subbasins to which pumping is transferred.

2.6 Costs

We have provided limited discussion of costs thus far because the capital, operations and maintenance costs of the assessed actions are expected to be minimal. Costs for meeting standard conditions are not considered WMA-related. Costs for activities under a water efficiency program that are beyond those in the standard permit conditions would qualify as WMA-related costs. However, as shown in Exhibit 20, these costs are less than $3,000 per year.

The wastewater discharge credit requires consultation with MassDEP and tracking of discharge flows in future years to ensure the offset continues to exist at required levels. For surface water releases, the storage volumes are small and, therefore, the construction and management cost is considered negligible when annualized over a 20-year permit period. In addition, surface water releases are significantly less expensive than other options such as stormwater redevelopment and retrofit or infiltration and inflow (I/I) removal.[19] This is demonstrated in results of the SuAsCo WMOST modeling where the model only selected surface water releases to meet streamflow targets. Finally, depending on the extent of source optimization, the system changes listed in Section 1.2.2 may be required. Since these system changes serve other purposes for WDPW, the costs are not strictly WMA-related.

2.7 Assessment of Potential Improvements in Cedar Swamp

The Jackstraw and Sandra subbasins have registered sources, contain CFRs and discharge to Cedar Swamp. Cedar Swamp is an Area of Critical Environmental Concern, an important ecological resource and is located at the headwaters of the Sudbury River. We evaluated the potential reallocation of pumping among source subbasins to provide improvements in aquatic habitat and late summer streamflow for the two subbasins and the critical Cedar Swamp habitat. WDPW, MassDEP, OARS and other stakeholders may discuss acceptable terms for enhancing these aquatic resources while maintaining WDPW’s access to its registered withdrawal volumes without additional requirements.

At least three options exist:

- First is the previously discussed volume available at Indian Meadows well that is fully offset by WWTP. This requires connecting the well to the Fisher plant (see Sections 2.4.1 and 2.5.1).
- The second option is releasing surface water from Sandra Pond to minimize impacts in that subbasin (Section 2.7.1).
- The third option is withdrawing additional volume from Chauncy wells and offsetting the impact with surface water releases from Lake Chauncy (Section 2.7.2).

The second and third options are discussed below.

[19] I/I in the sewer system are approximately 10 percent which is low for sewer systems. This would lead to higher than average costs for obtaining lower I/I values.

2.7.1 Sandra Pond Surface Water Releases

The CFR in the Sandra subbasin is located upstream and downstream of surface water withdrawals from Sandra Pond/Westborough Reservoir. For the downstream CFR and critical habitat, the reservoir outflow may be managed to provide sufficient streamflow to meet environmental needs. Input from DCR, OARS and other stakeholders is needed regarding minimum release patterns. Based on this input, WDPW can determine if the releases would affect existing withdrawal volumes and patterns and/or withdrawals potentially needed to meet minimization requirements in the SuAsCo subbasin. Financing the construction of refined outflow controls for the reservoir can be discussed among stakeholders.

In addition to the existing capacity at Sandra Pond, WDPW has commissioned an analysis for dredging Sandra Pond to restore and increase its capacity. This activity would incur significant costs and its utility depends on the environmental needs downstream and the ability of stakeholders to finance the project.

2.7.2 Jackstraw Pumping Reductions and Chauncy Offsets

For this assessment, we first calculated the pumping reductions in Jackstraw to achieve different GWCs. Second, we used WMOST to assess the potential for shifting pumping to Chauncy and offsetting the impacts.

Currently, pumping at the Morse and Hopkinton wells is necessary to keep chlorine circulating properly in the system. Based on system changes discussed in Section 1.2.2, WDPW may have the flexibility to shift pumping to other subbasins in the future and to reduce pumping from the Jackstraw subbasin.

Input is needed from DCR, OARS and other stakeholders regarding the flow needs of the CFR in the Jackstraw subbasin and the downstream Cedar Swamp. To evaluate the changes needed to improve streamflow, we compared the current pumping level in Jackstraw to the maximum pumping allowed in the subbasin for various GWCs. The average annual pumping in Jackstraw from 2010-2014 was 0.299 MGD and August pumping was 0.349 MGD. This level of pumping places Jackstraw in GWC 5. Using the August pumping from 2010-2014, we calculated the necessary reduction in August withdrawals to improve GWCs as shown in Exhibit 22.

Exhibit 22: August Withdrawal Reductions to Improve GWC in Jackstraw Subbasin[20]

GWC	Ratio of GW Withdrawals to Unaffected Streamflow for a GWC	Maximum Withdrawals Allowed for a GWC (MGD)	Reduction in August Withdrawals to Achieve GWC (MGD)
5	--	0.349	--
4	55%	0.255	0.094
3	25%	0.116	0.214
2	10%	0.046	0.284
1	3%	0.014	0.316

Note: Reductions are relative to an average August pumping of 0.349 MGD from 2010-2014.

To determine the extent to which pumping from Jackstraw can be shifted to the Chauncy wells, we modeled the Chauncy subbasin using WMOST. We setup the model to determine the average annual

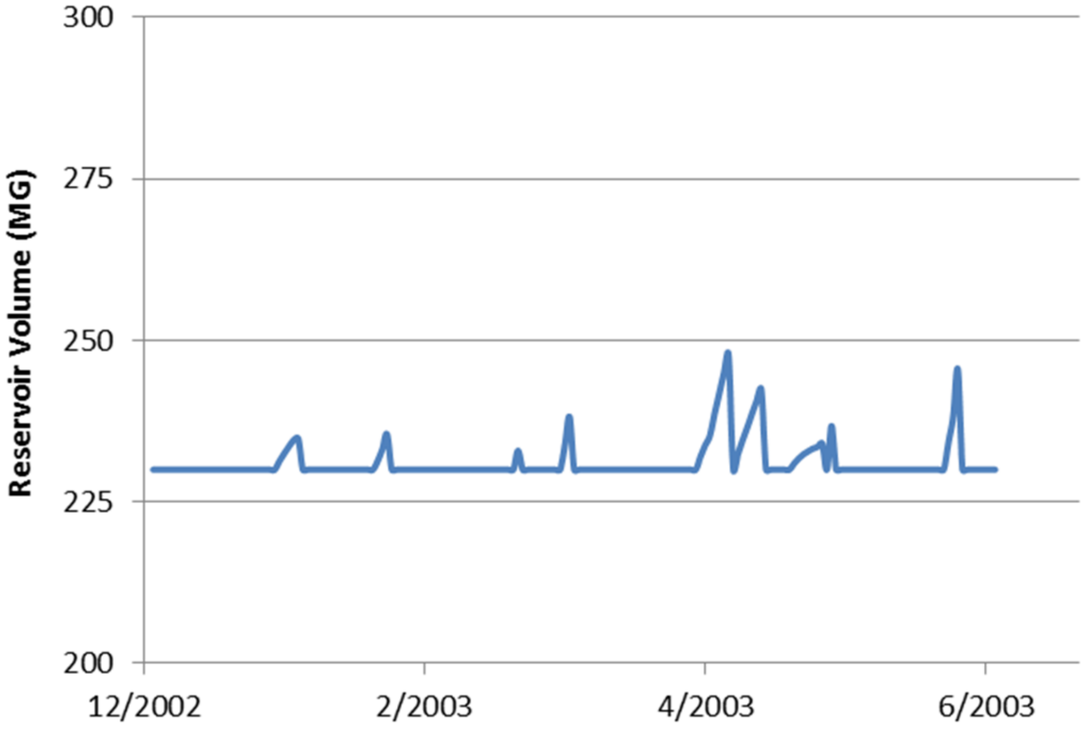
[20] We calculated the necessary reduction in groundwater withdrawals to achieve a higher GWC by subtracting the maximum allowed withdrawals for a category from the current August withdrawals.

withdrawals that could be made while meeting minimum instream flows via surface water releases. Appendix A provides modeling details. The options considered are the same as for the SuAsCo subbasin modeling described in Section 2.4.3. We considered two scenarios based on MassDEP's acceptance of the data refinement request.

In the first scenario, we assumed that MassDEP will accept the data refinement; therefore, we ran the model using 2010-2014 demand. This baseline run provided a time series of streamflow under the reduced demand condition of the 2010-2014 period. For the analysis model run, we used the minimum flows from the baseline run to specify minimum streamflow targets while calculating the *maximum possible* pumping. Results show that surface water releases can offset up to 0.69 MGD of pumping. This is 0.69 MGD additional to the 2010-2014 pumping of 0.03 MGD. The required maximum storage is 60 MG. This volume is a significant percentage of the current total volume of 230 MG. Exhibit 23 shows an excerpt of the reservoir storage volume time series.

Note that the analysis provides the maximum rate of pumping that could be shifted to the Chauncy wells while maintaining existing streamflow and still remaining below the total permitted pumping for the Chauncy wells of 1.29 MGD. Since total pumping in the Jackstraw subbasin is 0.35 MGD, the analysis shows that surface water releases would be a feasible approach to offset the impacts of any shift in pumping between the subbasins.

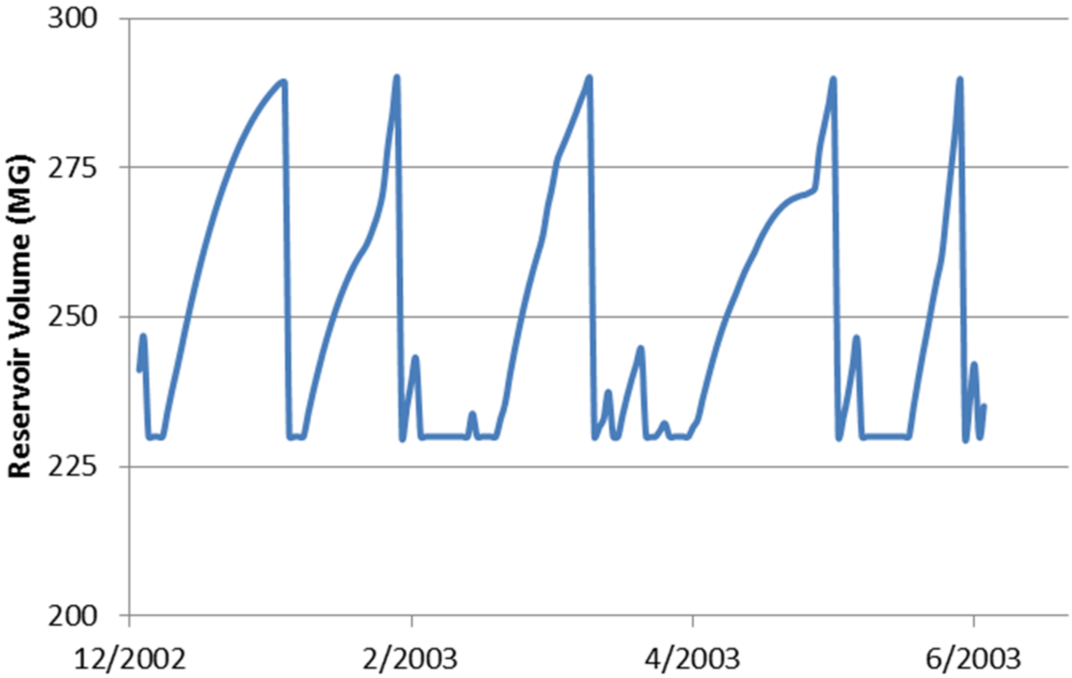
Exhibit 23. Modeled Volume for Chauncy Lake for 2010-2014 Conditions



Note: The reservoir volume is generally stable; fluctuations shown here are the storage and release of volume needed to meet streamflow targets.

For the second scenario, we assumed that MassDEP does not accept the data refinement; therefore we ran the model using the water demand in 2000-2004. We set the model to meet late summer bioperiod streamflow targets that would exceed the threshold for categorizing a subbasin as August net groundwater depleted. See Appendix A for detailed calculation of the targets. Results show that surface water releases can offset a total of 1 MGD of pumping while meeting AGND streamflow targets. Although this is only 0.6 MGD additional compared to 2000-2004 demand, it is 0.89 MGD additional compared to the 2010-2014 demand. Therefore, WDPW could shift 0.89 MGD to Chauncy subbasin and still meet ANGD streamflow targets. The maximum surface water storage control capacity required for this is 55 MG.[21] Exhibit 24 shows an excerpt of the reservoir storage volume time series.

Exhibit 24. Modeled Volume for Chauncy Lake for 2000-2004 Conditions



Note: The reservoir volume is generally stable; fluctuations shown here are the storage and release of volume needed to meet streamflow targets.

[21] Note that this volume is less than that calculated for the first scenario due to the lower minimum streamflow target specified for this second scenario.

3 WMA Permit Renewal Strategy

Based on the information and analyses in the previous sections, we summarize a strategy for WDPW permit renewal. As discussed through the report, several uncertainties exist in interpreting the Regulations and WMA guidance as they apply to WDPW. Therefore, the strategy includes multiple options for some requirements. WDPW may assemble their final CFR, minimization and mitigation plan from these options following consultation with MassDEP on the applicable requirements.

First, we provide the least-cost strategy for WDPW. MassDEP may not require all of these options.

- Unaccounted-for-Water
  - Conduct water audit and leak detection to determine sources of UAW
  - Implement plan to reduce to 10 percent to meet standard conditions
  - Consider achieving an UAW of less than 10 percent
  - This required standard condition reduces pumping which contributes to minimizing existing impacts *and* precludes or reduces the need for mitigation by staying below or close to the baseline
- Nonessential outdoor water use
  - Prepare administratively for a change to one or two days per week watering and to the streamflow trigger value
  - Initiate educational outreach to customers to achieve compliance and reduce use by the maximum extent possible
  - This required standard condition reduces pumping which contributes to minimizing existing impacts *and* precludes or reduces the need for mitigation by staying below or close to the baseline
- Water efficiency program
  - We estimated water savings of approximately 0.10 MGD for a five year water efficiency program with four simple measures at an annual cost of less than $3,000. This cost assumes a 50 percent rebate on the four conservation measures.
  - MassDEP review is needed to determine whether these measures are considered part of standard conditions or demand reduction prior to mitigation.
  - This action reduces pumping which contributes to minimizing existing impacts *and* precludes or reduces the need for mitigation by staying below or close to the baseline
- Source optimization
  - For CFRs, minimization and mitigation: Connecting the Indian Meadows well to the Fisher plant would provide 1.13 MGD of pumping that is entirely offset by the WWPT discharge.

- For the CFR and, potentially, for minimization in the SuAsCo subbasin: Based on 2010-2014 pumping and staying within the WDPW's registered withdrawal volume, WDPW can transfer approximately 0.53 MGD of pumping from the Andrews well field in the SuAsCo subbasin to the Jackstraw and Sandra subbasins. These two subbasins only have registered sources, are not subject to the Regulations and do not impose requirements on WDPW. This transfer would reduce approximately 80 percent of the pumping that affects the SuAsCo CFR.
- For minimization in SuAsCo and/or mitigation system wide: An additional 0.36 MGD of pumping may be transferred from Otis well in SuAsCo to the Jackstraw and Sandra subbasins without exceeding the registered volume. This transfer would contribute to potential minimization requirements in the SuAsCo subbasin if MassDEP does not approve wastewater discharge as minimization for the Otis well and WDPW does not choose to implement surface water releases for minimization.

- Wastewater discharge in the SuAsCo subbasin
  - Depending on MassDEP review, wastewater discharge may minimize some or all of the withdrawal impacts in the SuAsCo subbasin. At a minimum, pumping from Indian Meadows well is offset by the discharge. While this well has not been used since 2011 due to water quality, WDPW could connect the well to the Fisher street treatment plant. This well has a permitted volume of 1.13 MGD. WDPW may use this well's permitted volume of 1.13 MGD that is offset by the discharge and reduce pumping elsewhere to achieve minimization and/or mitigation.
- Surface water releases from SuAsCo reservoir
  - Depending on the extent of source optimization required for the SuAsCo CFR and MassDEP's determination of the wastewater discharge for minimization, WDPW may consider the option for surface water releases from the SuAsCo reservoir. Based on weather patterns in the 2000-2004 period which includes a 1in 3 dry year followed by a 1 in 20 dry year, WDPW would need to be able to store up to approximately 6 MG or 0.1 percent of the permanent pool to meet streamflow targets for GWC3 . SuAsCo is currently a GWC5.

Although these strategies should be sufficient for meeting requirements under the Regulations, we identified two additional options that we document here, should the need arise. First, the wastewater leach field at the old State Hospital site near Chauncy Lake could be re-opened to recharge wastewater and receive offset credit. WDPW would need to invest in estimating the capital and operations and maintenance cost of this option. Flow could be diverted from existing customers or from future growth in Westborough.

For stormwater recharge credits, WDPW has been proactive in requiring recharge from rooftops and parking lots during redevelopment. For this report, we worked with WDPW to document that 53.6 acres of impervious area have been retrofitted, amounting to 0.132 MGD of recharge. With upcoming municipal separate storm sewer systems (MS4) requirements, there may be opportunities for additional recharge credit as a co-benefit of meeting the MS4 requirements. Therefore, WDPW would benefit from continued tracking of stormwater projects that result in additional and quantifiable recharge.

The least-cost strategy for WDPW may not result in the best environmental outcomes. Withdrawals are not regulated in the Jackstraw and Sandra subbasins because these subbbasins have only registered withdrawals; therefore, WDPW's most cost-effective strategy is to maximize their use. However, both of these subbasins feed Cedar Swamp, an Area of Critical Environmental Concern and contain coldwater fishery resources. In addition, Jackstraw subbasin is a CFR with WDPW's withdrawals adjacent to the stream.[22] As such MassDEP, OARS and other stakeholders may wish to discuss with WDPW potential options for transferring registered withdrawals from the Jackstraw and/or Sandra subbasins to the Chauncy subbasin without incurring requirements for action. Input is needed from DCR, OARS and other stakeholders regarding the flow needs of CFR in the Jackstraw subbasin, Sandra subbasin (Piccadilly Brook) and Cedar Swamp to determine the extent to which transfers are needed to improve environmental conditions.

- WDPW pumped the two wells in Jackstraw subbasin at an average annual rate of 0.299 MGD and August average of 0.349 MGD during the 2010-2014 period. The registered volume for these two wells is 1.95 MGD. The wells are adjacent to the stream; therefore, reductions in pumping translate directly into reduced impact. Reductions in Jackstraw pumping benefit both the CFR in the subbasin and Cedar Swamp downstream; therefore, pumping reductions in this subbasin may be preferred over reductions in Sandra subbasin.

- WDPW may transfer withdrawals and/or release surface water from Sandra Pond to achieve environmental streamflow targets in the Sandra subbasin. WDPW's average annual and average August surface water withdrawals were 0.299 MGD and 0.349 MGD, respectively, during the 2010-2014 period. The registered volume for this source is 1 MGD.

- Chauncy subbasin has two groundwater wells adjacent to Chauncy Lake. Surface water releases from Chauncy Lake can offset withdrawals transferred from Jackstraw and/or Sandra subbasin. Based on weather patterns in the 2000-2004 period which includes a 1-in-3 dry year followed by a 1-in-20 dry year, approximately 0.89 MGD of pumping may be transferred to Chauncy wells in addition to pumping that occurred 2010-2014. A maximum storage capacity of 55 MG is needed to offset these withdrawals and continue to meet existing streamflows.

4 References

Lyons, J. 2015. Personal email communication between Alison Field-Juma from OARS and Jim Lyons from NRCS, Holden, MA on May 27, 2015.

Massachusetts Department of Environmental Protection. 2014. “Water Management Act Permit Guidance Document”. (November 2014) http://www.mass.gov/eea/agencies/massdep/water/watersheds/water-management-act-program.html

Data and reports used in the analyses are documented in Appendix A.3.

Appendix A WMOST Modelling

We used WMOST in this planning study to screen among water management options to meet WDPW customer demand while complying with requirements of the Regulations. WMOST is a public-domain software application designed to aid decision making in integrated water resources management. WMOST identifies the least-cost combination of management practices to meet the user specified management goals. The tool considers a range of management practices related to water supply, wastewater, nonpotable water reuse, aquifer storage and recharge, stormwater, low-impact development (LID) and land conservation, accounting for both the cost and performance of each practice.

In general, WMOST requires four categories of input data: watershed system, human water system, management costs, and effects of management practices on the watershed and/or human system. The general approach for the modeling study involved populating WMOST with data characterizing each of the systems. This process allows the user to better understand the dynamics and capabilities of the water system they are working with, and its constraints.

We ran validation scenario for each of our source water subbasins using data for the 2000-2004 time period without streamflow targets or management practices that would modify historic operations. We used these results to compare WMOST streamflow estimates to streamflow derived from the Massachusetts Sustainable Yield Estimator (SYE) data, adjusting the groundwater recession coefficient as needed to match the general pattern indicated by the SYE data.

The validation scenario also represents the period which is used to determine the Regulations' subbasin groundwater categories. Once we completed these validation runs, we used modelled streamflow values to calculate the minimization and mitigation streamflow targets for the planning scenarios. See Appendix A.5 for an explanation of how the streamflow targets were calculated.

A.1 WMOST Background

The following is an excerpt from WMOST Version 1 Theoretical Documentation and is intended to provide an introduction to WMOST. For more details, please refer to the full documentation available from the following EPA website: http://www2.epa.gov/exposure-assessment-models/wmost-10-download-page.

Objective of the Tool

The Watershed Management Optimization Support Tool (WMOST) is a public-domain software application designed to aid decision making in integrated water resources management. WMOST is intended to serve as an efficient and user-friendly tool for water resources managers and planners to screen a wide-range of strategies and management practices for cost-effectiveness and environmental sustainability in meeting watershed or jurisdiction management goals (Zoltay et al 2010).

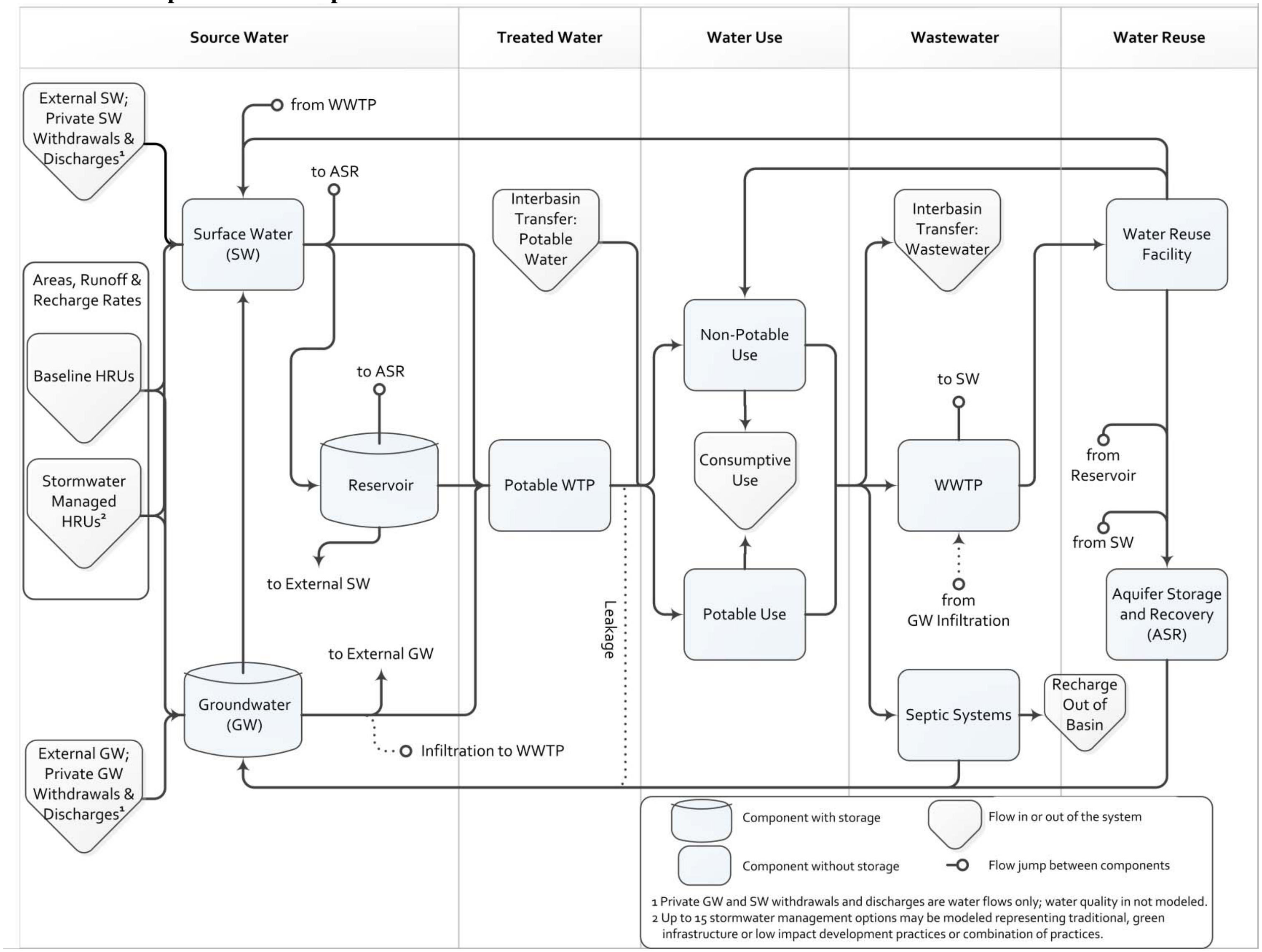
WMOST identifies the least-cost combination of management practices to meet the user specified management goals. Management goals may include meeting projected water supply demand and minimum and maximum in-streamflow targets. The tool considers a range of management practices related to water supply, wastewater, nonpotable water reuse, aquifer storage and recharge, stormwater, low-impact development (LID) and land conservation, accounting for the both the cost and performance of each practice. In addition, WMOST may be run for a range of values for management goals to perform a cost-benefit analysis and obtain a Pareto frontier or trade-off curve. For example, running the model for a range of minimum in-streamflow standards provides data to create a trade-off curve between increasing in-streamflow and total annual management cost.

WMOST is intended to be used as a screening tool as *part* of an integrated watershed management process such as that described in EPA's watershed planning handbook (EPA 2008), to identify the strategies and practices that seem most promising for more detailed evaluation. For example, results may demonstrate the potential cost-savings of coordinating or integrating the management of water supply, wastewater and stormwater. In addition, the tool may facilitate the evaluation of LID and green infrastructure as alternative or complementary management options in projects proposed for State Revolving Funds (SRF). As of October 2010, SRF Sustainability Policy calls for integrated planning in the use of SRF resources as a means of improving the sustainability of infrastructure projects and the communities they serve. In addition, Congress mandated a 20 percent set-aside of SRF funding for a "Green Project Reserve" which includes green infrastructure and land conservation measures as eligible projects in meeting water quality goals.

Overview

WMOST combines an optimization framework with water resources modeling to evaluate the effects of management decisions within a watershed context. The watershed system modeled in WMOST version 1 is shown in Exhibit 25. The exhibit shows the *possible* watershed system components and *potential* water flows among them.

Exhibit 25: Schematic representation of potential water flows in WMOST



The principal characteristics of WMOST include:

- Implementation in Microsoft Excel 2010© which is linked seamlessly with Visual Basic for Applications (VBA) and a free, linear programming (LP) optimization solver, eliminating the need for specialized software and using the familiar Excel platform for the user interface;
- User-specified inputs for characterizing the watershed, management practices, and management goals and generating a customized optimization model (see Exhibit 26 for a list of available management practices and goals);
- Use of Lp_solve 5.5, a LP optimization solver, to determine the least-cost combination of practices that achieves the user-specified management goals;
- Spatially lumped calculations modeling one basin and one reach but with flexibility in the number of hydrologic response units (HRUs)[23], each with an individual runoff and recharge rate;
- Modeling time step of a day or month without a limit on the length of the modeling period;[24]
- Solutions that account for both the direct and indirect effects of management practices (e.g., since optimization is performed within the watershed system context, the model will account for the fact 1) that implementing water conservation will reduce water revenue, wastewater flow and wastewater revenue if wastewater revenue is calculated based on water flow or 2) that implementing infiltration-based stormwater management practices will increase aquifer recharge and baseflow for the stream reach which can help meet minimum in-streamflow requirements during low precipitation periods, maximum in-streamflow requirements during intense precipitation seasons, and water supply demand from increased groundwater supply);
- Ability to specify up to fifteen stormwater management options, including traditional, green infrastructure or LID practices;
- A sustainability constraint that forces the groundwater and reservoir volumes at the start and end of the modeling period to be equal;
- Enforcement of physical constraints, such as the conservation of mass (i.e., water), within the watershed; and
- Consideration of water flows only (i.e., no water quality modeling)

Exhibit 26: Summary of WMOST management goals and management practices

Management Practice	Action	Model Component Affected	Impact
Land conservation	Increase area of land use type specified as 'conservable'	Land area allocation	Preserve runoff & recharge quantity & quality

[23] Land cover, land use, soil, slope and other land characteristics affect the fraction of precipitation that will runoff, recharge and evapotranspire. Areas with similar land characteristics that respond similarly to precipitation are termed hydrologic response units.

[24] While the number of HRUs and modeling period are not limited, solution times are significantly affected by these model specifications.

Exhibit 26: Summary of WMOST management goals and management practices

Management Practice	Action	Model Component Affected	Impact
Stormwater management via traditional, green infrastructure or low impact development practices	Increase area of land use type treated by specified management practice	Land area allocation	Reduce runoff, increase recharge, treatment
Surface water storage capacity	Increase maximum storage volume	Reservoir/Surface Storage	Increase storage, reduce demand from other sources
Surface water pumping capacity	Increase maximum pumping capacity	Potable water treatment plant	Reduce quantity and/or timing of demand from other sources
Groundwater pumping capacity	Increase maximum pumping capacity	Potable water treatment plant	Reduce quantity and/or timing of demand from other sources
Change in quantity of surface versus groundwater pumping	Change in pumping time series for surface and groundwater sources	Potable water treatment plant	Change the timing of withdrawal impact on water source(s)
Potable water treatment capacity	Increase maximum treatment capacity	Potable water treatment plant	Treatment to standards, meet potable human demand
Leak repair in potable distribution system	Decrease % of leaks	Potable water treatment plant	Reduce demand for water quantity
Wastewater treatment capacity	Increase MGD	Wastewater treatment plant	Maintain water quality of receiving water (or improve if sewer overflow events)
Infiltration repair in wastewater collection system	Decrease % of leaks	Wastewater treatment plant	Reduce demand for wastewater treatment capacity
Water reuse facility (advanced treatment) capacity	Increase MGD	Water reuse facility	Produce water for nonpotable demand, ASR, and/or improve water quality of receiving water
Nonpotable distribution system	Increase MGD	Nonpotable water use	Reduce demand for potable water
Aquifer storage & recharge (ASR) facility capacity	Increase MGD	ASR facility	Increase recharge, treatment, and/or supply
Demand management by price increase	Increase % of price	Potable and nonpotable water and wastewater	Reduce demand
Direct demand management	Percent decrease in MGD	Potable and nonpotable water and wastewater	Reduce demand
Interbasin transfer – potable water import capacity	Increase or decrease MGD	Interbasin transfer – potable water import	Increase potable water supply or reduce reliance on out of basin sources
Interbasin transfer – wastewater export capacity	Increase or decrease MGD	Interbasin transfer – wastewater export	Reduce need for wastewater treatment plant capacity or reduce reliance on out of basin services
Minimum human water demand	MGD	Groundwater and surface water pumping and/or interbasin transfer	Meet human water needs
Minimum streamflow	ft^3/sec	Surface water	Meet in-streamflow standards, improve ecosystem health and services, improve recreational opportunities

Exhibit 26: Summary of WMOST management goals and management practices			
Management Practice	**Action**	**Model Component Affected**	**Impact**
Maximum streamflow	ft^3/sec	Surface water	Meet in-streamflow standards, improve ecosystem health and services by reducing scouring, channel and habitat degradation, and decrease loss of public and private assets due to flooding

A.2 Data Collection and Assumptions

In general, WMOST requires four categories of input data: watershed system, human water system, management costs, and effects of management practices on the watershed and/or human system. Since the quality of the input data affects the reliability and accuracy of modeling results, a significant portion of the study focused on acquiring location-specific data and translating available data and expected WMA requirements for WDPW into appropriate modeling inputs and parameters.

Key data sources used for the study include:

- WDPW operational data on water sources, users, pumping rates, etc. (WDPW 2014),
- WMA Tool (MassDEP 2014a), which provides data for each of the subbasins, including estimated unimpacted August median streamflow, groundwater pumping rates, wastewater discharge rates, impervious cover percentage, and area in square miles,
- HSPF model of the Sudbury River (USGS 2010), which provides simulated runoff and recharge time series based on historical precipitation data in the vicinity of the three target subbasins,
- “Massachusetts Water Indicators” (WMI) report and associated data (USGS 2013), which provides seasonal estimates for private well users and septic return flows,
- Massachusetts Sustainable-Yield Estimator (MA SYE) (USGS 2010), which provides estimated streamflows for ungauged stream locations based on correlations between reference stream gauges and ungauged sites and 2000-2004 water withdrawals and discharges as well as an output of water withdrawal and discharge time series, and
- MassGIS for geospatial data on land use, surficial geology, and protected land areas.

Data processing to prepare WMOST inputs ranged from simply converting units or calculating demand time series for various user types (e.g., residential, commercial, etc. based on total pumping and percent user type) to extracting data from the HSPF simulation model and transforming it for use in WMOST.

The tool considers a range of management practices related to water supply, wastewater, nonpotable water reuse, aquifer storage and recharge, stormwater, low-impact development (LID) and land conservation, accounting for both the cost and performance of each practice. For this study, we considered the practices listed in Exhibit 27.

Exhibit 27: Management actions modeled in WMOST	
Practice	**Effect**
Stormwater management	Increase area of land use type treated by specified management practice to reduce runoff and increase recharge Practices considered: infiltration basin, bioretention areas and dry ponds at the 0.6’’, 1’’ and 2’’ design depths
Surface water storage capacity	Store spring flows in SuAsCo Reservoir for release during low-flow periods, propose to accomplish by using stop logs at the outlet weir to manage the water levels (SuAsCo only)
Surface water pumping capacity	Add pumping capacity to reduce quantity and/or timing of demand from other sources
Groundwater pumping capacity	Add pumping capacity to reduce quantity and/or timing of demand from other sources
Change in quantity of surface versus groundwater pumping	Change in pumping time series for surface and groundwater sources to change the timing of withdrawal impact on water source(s) to alleviate low-flows
Potable water treatment capacity	Increase maximum treatment capacity to meet potable human demand
Leak repair in potable distribution system	Decrease the percentage of leaks to reduce demand for water quantity
Water reuse facility capacity	Add advanced treatment to wastewater treatment facility to produce water for nonpotable demand and/or ASR
Nonpotable distribution system	Add secondary distribution system to reduce demand for potable water
Aquifer storage & recharge (ASR) facility capacity	Add ASR facility to recharge groundwater supply especially during high flows

We did not consider the following management actions:

- Land conservation: Preserving existing forest and other undeveloped land is an indirect measure and will be considered by MassDEP only once direct measures have been exhausted or proven cost prohibitive. Therefore, we excluded this option from the primary runs.

- Sandra Pond dredging: The storage capacity of the pond may be increased with dredging. WDPW commissioned a feasibility analysis which suggests significant costs associated with this activity.

Key assumptions for scenarios are summarized below. The data catalogs in Appendix B provide more details.

- Planning horizon and financing. We assume a 20-year planning period based on the WMA water withdrawal permit cycle. We use an interest rate of 3 percent for financing the capital cost of infrastructure. New capital cost investments in the model are therefore amortized over 20 years at a rate of 3 percent.

- Replacement costs. There is (at least) 25 years remaining lifetime on existing structures and therefore we assume no replacement costs within the simulation period.

- Land use. Regulations do not require accounting for projected changes in land use (which will affect runoff and recharge rates); therefore, we used 1999 land use to define the subbasins, the year of available data closest to the 2000-2004 baseline period.

- Climate. We run scenarios using runoff and recharge coefficients that reflect precipitation patterns in 2000 to 2004 time period. Hydrologic conditions included a 1 in 3 dry year in 2001 followed by a 1 in 20 dry year in 2002.[25]

- Demand and Pumping Time Series. We scaled 2000-2004 daily pumping time series to the current, 2010-2014, and removed water volumes based on the model setup to create the demand time series for the minimization (see Section 2.1.2) and further explanation below. We scaled the 2000-2004 time series rather than using 2010-2014 pumping data in order to keep consistency between human use to weather patterns (e.g., high withdrawal during hot days and weeks).

- UAW. We assume a starting UAW of 10 percent in both the minimization and mitigation scenarios since this is a standard permit condition.

- Demand management: Reducing demand is the first requested or most preferred action under the Regulations. We estimated potential demand management prior to model runs due to regulatory preference for demand reduction first and no current capability in WMOST for dynamic outdoor water conservation (i.e., demand management only affecting specific months). This reduced the number of scenarios to run and ensures the implementation of these practices first.

  Reducing demand reduces revenue. Given that some existing costs for utilities are fixed (i.e., they do not vary with volume of water provided), demand management may require simultaneous adjustment in water rates to maintain full cost recovery.

  Westborough is already below the average RGPCD limit set by the Regulations and has implemented nonessential outdoor water use restrictions during the months May through September (see Section 2.2). We estimated additional capacity for demand management as follows:

  - Outdoor use: The Regulation provides options for outdoor water conservation based on the calendar (i.e., May through September) or based on low-flow triggers. Currently, WDPW is required by their WMA permit to enact watering restrictions when the low streamflow target is triggered. WDPW only restricts hourly outdoor watering, i.e. users can only water between the hours of 9 AM and 5PM, and does not restrict users to a weekly watering schedule. In future years, WDPW will adopt one- or two-day per week schedule depending on streamflow. This will provide additional water savings during peak use periods that overlap with the critical late summer bioperiod.[26]

    We estimated the savings from implementing two-day a week outdoor water use based on the experience of the Towns of Franklin and Scituate. Based on preliminary results from Horsley

[25] Calculated using data from Boston precipitation station from 1961 to 2005 and the methodology presented at: http://drought.unl.edu/MonitoringTools/DownloadableSPIProgram.aspx

[26] Low flows are primarily experienced in the late summer after extended periods with reduced precipitation, increased evapotranspiration and increased human use. A significant portion of human use during the growing season (approximately May to September) is attributable to outdoor watering. The efficiency of outdoor watering may be increased via moisture sensors, installation of low water need/drought resistant landscaping, and other practices that are under the control of the customer.

Witten Group's analysis of Franklin and Scituate data, we assumed near-term[27] reductions of 15 percent in outdoor summer use (HWG 2014). We calculated outdoor water use as the difference between the average daily demand for the summer months (June through September), when outdoor watering is expected, and the winter months (December through February), when outdoor watering is not expected[28]. We reduced the summer outdoor use portion of demand by 15 percent to calculate a new time series of total demand and new consumptive use percentages assuming that the reduction is 100 percent consumptive use.

– Indoor use: We used the Water Efficiency Calculator[29] to determine the maximum possible reduction in demand if WDPW sponsored a 50 percent rebate on common water conservation measures. We assumed that WDPW would offer four products, three water efficient fixtures for indoor residential use and one large-scale offering for commercial entities, over the course of five years. The average daily demand reduction as a result of this program is estimated to be 0.10 MGD with a net cost of roughly $536,000 to WDPW over five years.

Demand management does not affect unaccounted-for-water (UAW). Specific water pressure must be kept in the distribution system for customers and health and safety reasons and this is the important factor, not the volume of water flowing through the system. Demand management practices outline above also would not affect other sources of UAW such as metering errors. This analysis and WMOST treats UAW separately from more traditional demands such as residential, commercial, municipal and industrial.

- Stormwater Management. We used EPA's SUSTAIN model to modify HSPF runoff and recharge rate time series to reflect the installation of stormwater practices. The model considers implementation of bioretention areas, infiltration basins, and detention basins at the 0.6-inch, 1-inch and 2-inch design depths. We determined the maximum area available for stormwater retrofit of existing development within the Town of Westborough for each type of land use and soil combination that existed in 1999 after removing all areas that have been stormwater retrofitted. In addition, we excluded all land uses with no impervious area (such as forested or wetland areas) and Zone II hydrologic areas, which are areas that have recharge requirements and, therefore, may have limited additional recharge potential.

[27] While the analysis showed 13% to 23% savings within the first five years, longer term savings were estimated at 34% and attributed to increasing acceptance and embracing of the bylaw requirement.

[28] HWG analysis estimated outdoor use as the average month's use minus the minimum month's use. This difference in calculating outdoor water use may require an adjustment to the assumed percent reduction. Since we used the more conservative near-term reductions for WMOST modeling, it is unlikely that values surpass the long term savings of 34 percent that may be expected during the course of a 20-year permit.

[29] The Water Efficiency Calculator was developed by Abt Associates et al 2015 developed under the 2014 SWMI grant to the Town of Wrentham.

A.3 Data Catalog for Westborough Input Data

Input Data	Units	12010	12020	12026	12027	Notes
Land Use						
Number of land uses/HRUs	Numerical value	14	14	12	12	Based on delineation in Sudbury-Assabet HSPF watershed simulation model
Stormwater Management Sets	Numerical value	9	9	9	9	Infiltration basin, bioretention area, and detention basins at 3 depths: 0.6", 1.0", 2.0". USGS Sudbury-Assabet HSPF Model Output modified using SUSTAIN
Existing land use for each HRU	Acres	Varies by HRU and subbasin, see model interface				Intersection of MassGIS 1999 Land use and Surficial Geology layers, crosswalked to HSPF HRU categories. For land conservation maximum areas, all land that has been conserved are removed.
Minimum area for each HRU	Acres	0				
Maximum area for each HRU	Acres	Existing HRU areas with all existing conservation areas removed				
Capital cost to conserve land use/HRU	$/acre	105,263				Realtor listings for vacant land in Westborough
O&M cost to conserve land use/HRU	$/acre/yr	1,053				1% of capital cost
Stormwater Management						
Capital cost	$/acre	Varies based on stormwater BMP and size				Based on data in TetraTech (2010) Stormwater BMP Performance Analysis
O&M cost	$/acre/yr	5% of capital costs				Default value
Runoff and Recharge						
Recharge rates for each unmanaged HRU	in/day	See model interface for time series or summary table of average annual values in report Appendix				Based on delineation in Sudbury-Assabet HSPF watershed simulation model
Runoff rates for each unmanaged HRU	in/day					
Recharge rates for each stormwater managed HRU	in/day					HSPF watershed simulation outputs modified with SUSTAIN
Runoff rates for each stormwater managed HRU	in/day					
Water Demand						
Number of water user types	Numerical value	5 (including UAW)				Residential, commercial, industrial, municipal, UAW (based on WDPW data)

Input Data	Units	12010	12020	12026	12027	Notes
Demand for each user for each day	MG/time step	See model interface for time series				-Monthly water pumping time series (2000-2004), scaled up to current (2010-2014) and DCR project 20-year demand -Percent of water use by type based on WDPW data and 10% UAW to meet standard permit conditions
Percent consumptive use for each water user for each month	%	Oct-Mar 4%; April 6%; May-Sept 20-29% (see model interface for specific monthly values)				Based on data in Amy Vickers (2002) Handbook of Water Use and Conservation
Nonpotable water						
Maximum percent demand that can be met by nonpotable water for each user	%	Ranges from 4 to 90%, see model interface				Based on data in Amy Vickers (2002) Handbook of Water Use and Conservation
Percent consumptive use for nonpotable water for each user for each month	%	Ranges from 1 to 24%, see model interface				Based on data in Amy Vickers (2002) Handbook of Water Use and Conservation
Septic						
Percent septic use for public water user draining inside the study area	%	0	4	1	1	Septic populations determined by population outside of the WDPW sewer main reaches, approximately 10% of the Town of Westborough
Percent septic use for public water user draining outside the study area	%	10	6	9	9	
Surface Water						
Reservoir Storage						
Initial reservoir volume	MG	173	7,826	No reservoirs	123	Initial reservoir volume was considered to be 75% of the maximum volume
Minimum reservoir volume	MG	115	4,984		16.4	Minimum reservoir volume determined by management of the reservoir. If no active management of the reservoir, 50% of maximum volume was considered the default
Current maximum reservoir volume	MG	230	10,435		164	Maximum reservoir volume data gathered from reservoir reports or estimation via reservoir bathymetry
Capital construction cost	$/MG	50,000	50,000		0	Estimated costs to represent the costs of managing surface water releases at the reservoir. Sandra Pond is already managed by the town so cost of surface water releases is negligible.
O&M costs	$/MG	5,000	5,000		0	
Streamflow						
Inflow from external surface water	cfs	0				Headwater subbasins, therefore no inflow from upstream
Minimum in-stream flow standards	cfs	See model inputs				Values set based on 2000-2004 flows plus needed improvements to reach various minimization targets

Input Data	Units	12010	12020	12026	12027	Notes
Minimum surface water discharging outside of study area	cfs	Standard was not used				
Private withdrawals of surface water	MG/time step	SYE/MWI derived data disaggregated to daily time series, see report for details on methodology				Timeseries outputs from Massachusetts Sustainable Yield Estimator (SYE). No private withdrawals exist in Westborough.
Private discharge of surface water	MG/time step					Timeseries outputs from Massachusetts Sustainable Yield Estimator (SYE). No private discharges exist in Westborough.
Groundwater						
Groundwater recession coefficient	1/time step	0.04	0.045	0.018	0.04	HSPF Sudbury-Assabet model: [1 - (area-weighted average of AGWRC across HRUs)] based on distribution of HRUs in each subbasin. The calculated groundwater recession coefficient was altered during calibration, and the calibrated coefficients are shown.
Initial groundwater volume	MG	90	2,304	30	299	Back calculated based on SYE streamflow for month 1 of time series and groundwater recession coefficient
Minimum volume	MG	0	0	0	0	Default setting
Maximum volume	MG	9,050	23,037	4,005	2,993	Default values used so that recharge level are not limited
Flow from external groundwater	cfs	0	0	0	0	Headwater subbasins, therefore no inflow from upgradient areas
Private withdrawals of groundwater	MG/time step	SYE/MWI derived data disaggregated to daily time series, see report for details on methodology				Timeseries outputs from Massachusetts Sustainable Yield Estimator (SYE). No private withdrawals exist in Westborough.
Private discharge of groundwater	MG/time step					Timeseries outputs from Massachusetts Sustainable Yield Estimator (SYE). No private discharges exist in Westborough.
Interbasin Transfer						
Purchase price for IBT potable water	$/MG	No Interbasin Transfer scenarios considered in subbasins				
Initial cost for new/additional IBT potable water	$/MGD					
Maximum additional capacity for water and wastewater	MGD					
Infrastructure						
Planning horizon	years	20				Default setting
Interest rate	%	3				
Water Treatment Plant						
Customer's fixed price for potable water	$/month	13				Average monthly charge applied to users in 2015 based on flow-weighted average of pricing bracket
Customer's variable price for potable water	$/HCF	6.09				Average flow-weighted price to users for water

Input Data	Units	12010	12020	12026	12027	Notes
Gw pumping – Capital construction cost	$/MGD	5,787,037				Based on previous Littleton study estimate for developing a new well source
Gw pumping -O&M costs	$/MG	1,717	1,717	1,717	0	WDPW O&M costs for producing water in 2014 (groundwater and surface water wells)
Gw pumping -Current max capacity	MGD	1.296	3.961	0.95	0	Maximum existing pumping capacity of wells in each subbasin
Gw pumping lifetime -remaining on existing construction	years	25				Values set higher than planning horizon to exclude replacement costs from analysis
Gw Pumping lifetime- new construction	years	35				
Sw pumping – Capital construction cost	$/MGD	453,885				Based on previous Danvers-Middleton MA case study (EPA 2013)
Sw pumping -O&M costs	$/MG	0	0	0	1,717	WDPW O&M costs for producing water in 2014 (groundwater and surface water wells)
Sw pumping -Current max capacity	MGD	0	0	0	1.2	No existing capacity in Chauncy, SuAsCo, or Jackstraw. Maximum daily observed pumping in Sandra Pond
Sw pumping lifetime -remaining on existing construction	years	25				Values set higher than planning horizon to exclude replacement costs from analysis
Sw Pumping lifetime- new construction	years	35				
Wtp - Capital construction cost	$/MGD	6,229,186				Based on previous Littleton study (Abt Associates et al, 2014)
Wtp -O&M costs	$/MG	0				O&M costs included as groundwater pumping or surface water pumping
Wtp lifetime -remaining on existing construction	years	25				Values set higher than planning horizon to exclude replacement costs from analysis
Wtp lifetime- new construction	years	35				
Wtp-Current max capacity	MGD	1.3	4	1.16	0	Maximum pumping capacity of wells in each subbasin
Capital cost of survey & repair	$	708,981				Cost for survey of all WDPW mains
O&M costs for continued leak repair	$/year	0				Assumed that WDPW fixes all leaks to achieve 10% UAW as part of the standard permitting conditions
Maximum percent of leaks that can be fixed	%	0				
Wastewater treatment plant						
Customer's fixed price for potable water	$/month	11.73				Average monthly charge applied to users in 2015 based on flow-weighted average of pricing bracket
Customer's price for wastewater	$/HCF	5.23				Average flow-weighted price to users for sewer
Capital construction cost	$/MGD	0				Increase in capacity to WWTP was not considered

Input Data	Units	12010	12020	12026	12027	Notes
Charges based on water or wastewater?	water or wastewat-er	water				Based on WDPW 2015 sewer rates
O&M costs	$/MG	313				O&M costs based on the size of the WWTP and related O&M costs
Lifetime remaining on existing construction	years	25				Values set higher than planning horizon to exclude replacement costs from analysis
Lifetime of new construction	years	35				
Current maximum capacity	MGD	2.89				Maximum capacity for the Town of Westborough at the shared WWTP
Initial groundwater infiltration into WW collection system	%	4				Based on level of I/I determined by the Comprehensive Wastewater Management Plan
Water reuse facility						
Capital construction cost	$/MGD	18,644,791				Values from Littleton study (Abt Associates et al, 2014)
O&M costs	$/MG	1,305,135				
Lifetime remaining on existing construction	years	0				No initial capacity. Lifetime value set higher than planning horizon to exclude replacement costs from analysis
Lifetime of new construction	years	35				
Current maximum capacity	MGD	0				No existing capacity
Nonpotable water distribution system						
Consumer cost for nonpotable water	$/HCF	3				Values from Danvers-Middleton case study (EPA 2013)
Capital construction cost	$/MGD	12,529,440				
O&M cost for nonpotable distribution system	$/MG	1,716				
Aquifer Storage and Recovery						
Capital construction cost	$/MGD	1,965,727				Values from Danvers-Middleton case study (EPA 2013)
O&M costs	$/MG	538				
Lifetime remaining on existing construction	years	0				No initial capacity. Lifetime value set higher than planning horizon to exclude replacement costs from analysis
Lifetime of new construction	years	35				
Current maximum capacity	MGD	0				No existing capacity
MEASURED FLOW						

Input Data	Units	12010	12020	12026	12027	Notes
Measured flow	cfs	Time series from 2000-2004, see model interface				SYE flows adjusted for withdrawals and discharges with MWI data

Input Data References

DeSimone, LA, Walter, DA, Eggleston, JR, and Nimroski, MT, 2002. *Simulation of Ground-Water Flow and Evaluation of Water-Management Alternatives in the Upper Charles River Basin, Eastern Massachusetts*. Water-Resources Investigations Report 2002-4234. U.S. Geological Survey, Westborough, Massachusetts.

U.S. Environmental Protection Agency (EPA) 2010. *Stormwater Best Management Practices (BMP) Performance Analysis.* Prepared by TetraTech for United States Environmental Protection Agency – Region 1, Boston, Massachusetts. Fairfax, Virginia.

U.S. Geological Survey (USGS). 2010. Effects of Water Use and Land Use on Streamflow and Aquatic Habitat in the Sudbury and Assabet River Basins, Massachusetts, Scientific Investigations Report 2010–5042, (prepared by Phillip J. Zarriello, Gene W. Parker, David S. Armstrong, and Carl S. Carlson)

A.4 Validation Of WMOST Models

The purpose of the validation scenario is to verify the model's ability to simulate known conditions during the period of 2000 through 2004.[30] In the absence of measured flows, the first modeling step was to compare WMOST streamflow — derived based on mechanistic modeling using HSPF runoff and recharge values, WDPW data, and MWI/SYE data — to MA SYE streamflow, derived based on a regression of gaged streams to ungauged streams and adjusted for human impact using MWI data. For one subbasin, Chauncy, the USGS SWMI subbasin and the Sudbury-Assabet HSPF model overlapped the same land area so we compared the flows in Chauncy to both MA SYE streamflow and HSPF streamflow. Exhibit 28 summarizes key specifications for the validation scenario.

Exhibit 28: Summary of validation scenario specifications

Data/Assumption	Values
WDPW demand	2000-2004 (based on SYE/WMA pumping data) Demand assigned to each subbasin based on the pumping regime observed in the 2010-2014 period
Customer price for water	Based on 2010-2014 data of WDPW revenue from water sales
Non-WDPW withdrawals and discharges	2000-2004 SYE/WMA Tool water use and discharge flows
Management actions	None available
Management costs	2010-2014 O&M costs (based on expenses for electricity, natural gas, and chemicals; does not include bond payments or asset depreciation)
Streamflow target	None

We determined the agreement between the two modeled monthly streamflows by calculating the Nash-Sutcliff Efficiency (NSE) over the entire modeling period of five years and for the five low flow bioperiods between July and September. NSE is one metric for assessing the predictive value of hydrologic models. NSE values can range from 1.0 (perfect fit) to negative infinity. An efficiency of lower than zero indicates that the mean value of the observed time series would have been a better predictor than the model. In calculating the NSE, we assumed that the SYE and HSPF flows are observed flows and WMOST flows are modeled flows.

Exhibit 29 below summarizes the NSE coefficients for the Chauncy WMOST model compared to SYE flows and HSPF flows, as well as the HSPF model compared to SYE flows.[31] On an annual basis, the WMOST model and the HSPF model are most similar. However, when the late summer bioperiod is considered, the WMOST model compares favorably to SYE streamflow. Exhibit 30 shows an example graph comparing the streamflow time series for WMOST, MA SYE, and HSPF for the Chauncy subbasin. As shown in the time series, WMOST does not match the episodic peak flows in SYE and better follows the pattern and magnitude of HSPF flows. The two models show better agreement during low flow periods, as reflected in the higher NSE values for the low flow bio-periods in Exhibit 29.

30 We chose this time period because it served as the basis for MassDEP's determination of the "baseline withdrawals" for the Regulations and as such there is sufficient data on all regulated withdrawals and discharges in each subbasin.

31 MA SYE tool does not include septic returns or private withdrawals. When running the MA SYE tool, we used MWI reported septic return flows. We adjusted the resulting MA SYE flows for private withdrawals based on seasonal MWI values.

Exhibit 29: Comparison statistics for WMOST model, relative to SYE streamflow and HSPF streamflow, for Chauncy			
Period	**NSE Value**		
	WMOST compared to SYE	**WMOST compared to HSPF**	**SYE compared to HSPF**
Annual[1]	0.67	0.77	0.65
Late Summer Bioperiod[2]	0.75	0.71	0.84

(1) Based on 5-year monthly streamflow during January-December.
(2) Based on 5-year monthly streamflow during July-September.

Exhibit 30: Comparison of WMOST, MA SYE, and HSPF streamflow in Chauncy

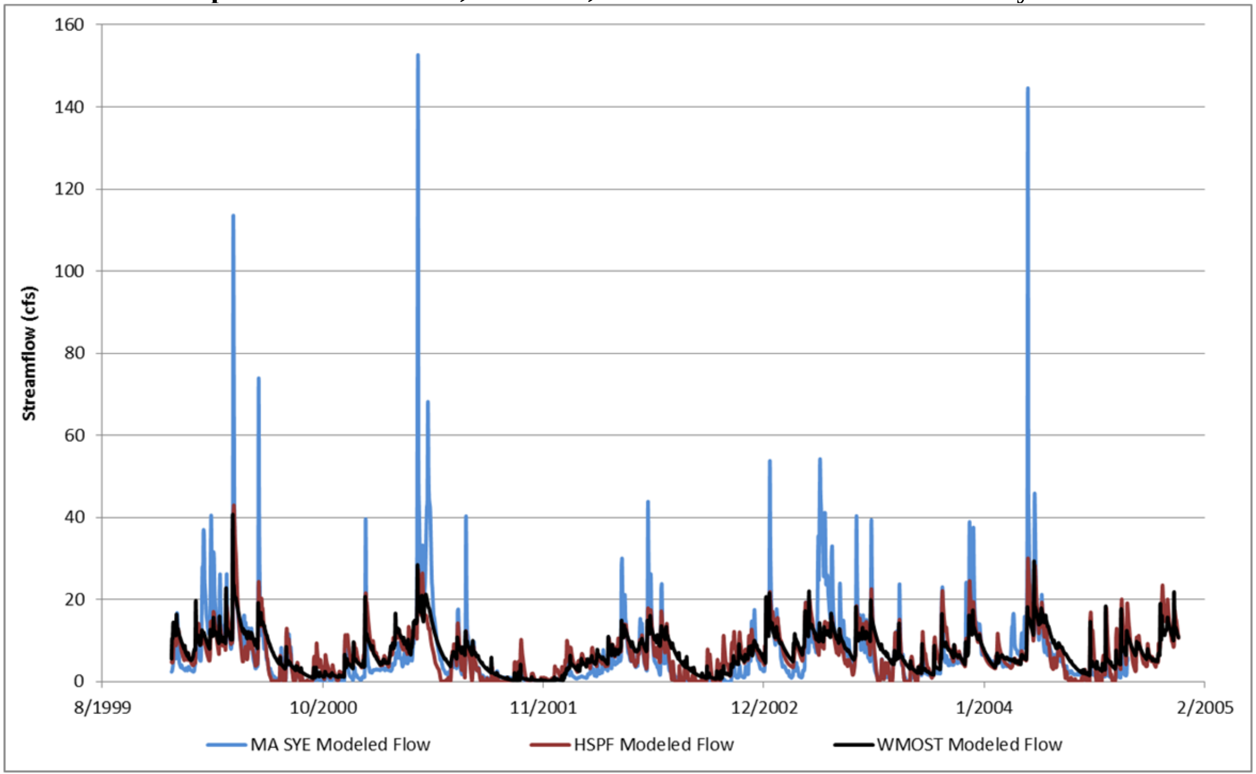
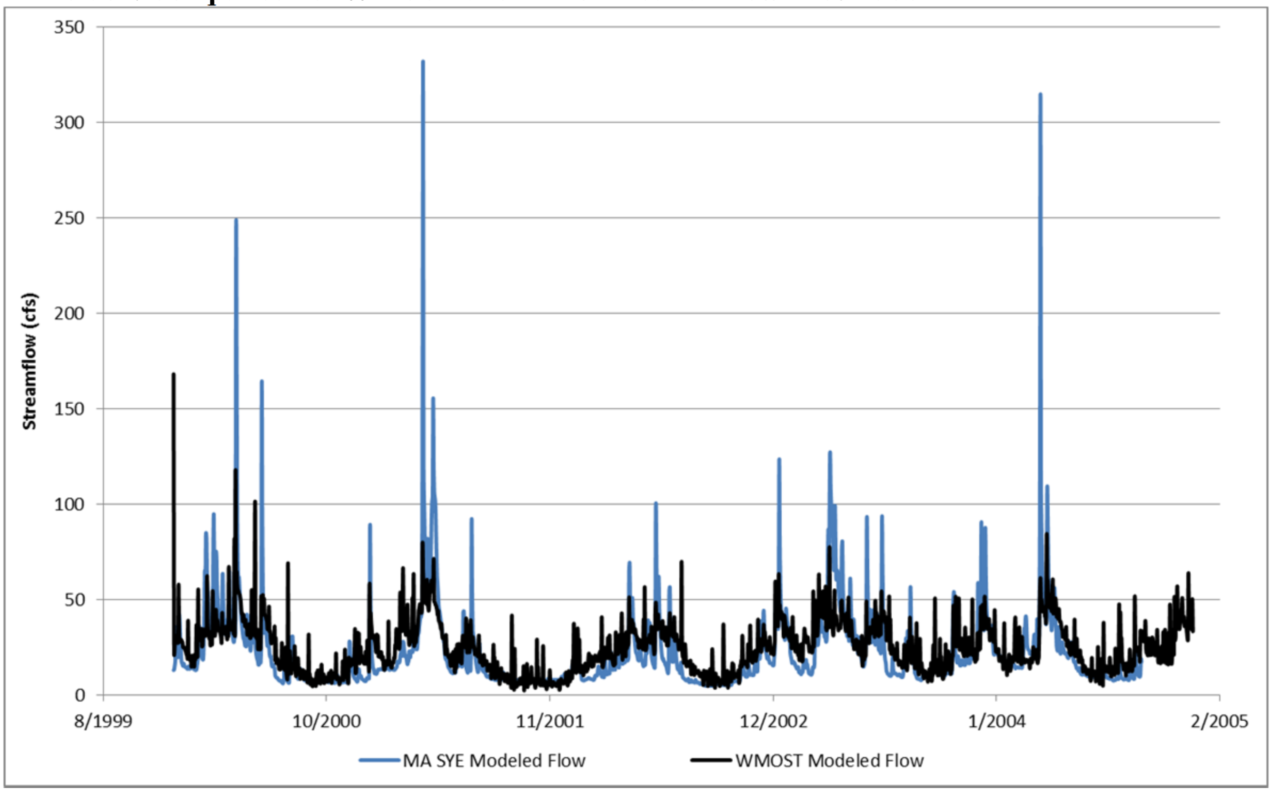


Exhibit 31 summarizes the the NSE coefficients for the SuAsCo WMOST model compared to SYE flows. The SuAsCo subbasin did not have a match in the HSPF subbasin model so we were not able to compare the SuAsCo flows to the HSPF model flows. The SuAsCo model shows NSE coefficient values in the same range as the Chauncy model. The SuAsCo NSE coefficient values are slightly higher and display the same relationship between the annual and late summer bioperiod values. Exhibit 32, below, shows the timeseries comparison of the WMOST modeled flows and the SYE modeled flows.

Exhibit 31: Comparison statistics for WMOST model, relative to SYE streamflow, for SuAsCo	
Period	**NSE Value**
Annual[1]	0.75
Late Summer Bioperiod[2]	0.78

(1) Based on 5-year monthly streamflow during January-December.
(2) Based on 5-year monthly streamflow during July-September.

Exhibit 32. Comparison of WMOST and MA SYE streamflow in SuAsCo



The fit between WMOST modeled streamflow and SYE modeled streamflow depends on, and is limited by, the representation of the hydrologic processes in WMOST, the accuracy of the HSPF model from which we obtained runoff and recharge values and the accuracy of the SYE model to which we compare the simulated streamflow. We transferred the runoff and recharge rates and groundwater recession coefficient appropriate for the land use and surficial geology in the three subbasins into WMOST directly from the HSPF model without performing further adjustments or calibration. This is similar to previous applications of WMOST where we used HSPF data and did not calibrate any parameters.

The streamflow comparison and NSE statistics show that WMOST provides acceptable estimates of the low flows that are the key consideration in LWD's planning decisions relative to meeting the Regulations.

A.5 Streamflow Target Calculation

We developed streamflow targets for each modeled subbasin to drive the WMOST model to apply water management actions to the subbasin system to meet the minimum streamflow standards. The method used to develop the streamflow targets varies between subbasin scenarios and are explained below.

For the Chauncy subbasin model, we ran the same scenario with two different sets of monthly streamflow targets. The first set of targets applied to the model represents the minimum streamflow needed to meet the 25 percent AGND required for minimization in the Regulations. In Section 2.1, we presented WDPW data that showed an improvement in the AGND for Chauncy in the 2010-2014 time period, which, if accepted by MassDEP, would release WDPW from needing to minimize its impacts in that subbasin. In case the data refinement presented is not accepted by MassDEP, we performed a model run with Chauncy that applied minimum streamflow targets in August to meet the 25 percent AGND requirement for minimization. The second set of targets reflects the assumption that MassDEP accepts the data refinement for Chauncy, and thus, no minimization in the subbasin is necessary.

The streamflow targets applied in the Chauncy and SuAsCo minimization scenarios are based on the minimum monthly streamflow in the output of the WMOST validation run that reflects the Regulations standard permitting conditions (i.e. limit of 10 percent UAW). Therefore, we altered the demand time series from the validation run to reflect the standard permitting conditions and determined the minimum monthly streamflow from the altered model run.

The minimum monthly flows do not incorporate any streamflow conditions improvement, so in order to analyze the system under improved streamflow and groundwater conditions, we added the flow offset necessary to decrease the ANGD percentage below 25 percent. Exhibit 9 shows the process of the calculating the offset and adding the offset flow to the August minimum streamflow.

Exhibit 9: Determination of Streamflow Targets for Minimization scenarios in Chauncy and SuAsCo

Calculations Involved in Streamflow Target Determination	Chauncy	SuAsCo
Unaffected August Flow (cfs)	1.25	2.58
Maximum withdrawal to meet 75% of unaffected August streamflow (cfs)	0.31	0.65
Average August Withdrawals (cfs)	0.56	1.53
Average August Recharge (cfs)	0.12	0.14
Reduction in withdrawals needed (cfs)	0.12	0.74
August minimum streamflow from WMOST validation (cfs)	0.71	2.02
Minimum in-stream flow target to meet 75% of unaffected flow	0.83	2.76

We also ran the Chauncy model with streamflow targets that did not incorporate an offset amount that would improve the ANGD conditions. For this scenario, we used the minimum monthly streamflow from the validation run with standard permitting conditions for each month with no additional flow added. We used this scenario to determine the greatest volume of withdrawals possible to meet the same streamflow as the 2000-2004 period.