Department of Public Services
Newburyport, Massachusetts

Watershed Protection Plan

City of Newburyport

September 2021

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Executive Summary

The City of Newburyport receives its water from three interconnected surface reservoirs, one isolated surface pond, and two groundwater supply wells, with the majority of the water coming from the three interconnected surface reservoirs: Indian Hill, Upper Artichoke, and Lower Artichoke. The Indian Hill Reservoir spills over its dam and flows downstream via a natural stream channel to the Upper Artichoke Reservoir, which is held back by a dam that discharges directly into the Lower Artichoke Reservoir. The Lower Artichoke Dam is controlled by a concrete spillway and earthen dam that spills into the Artichoke River. A pumping station adjacent to the Lower Artichoke Reservoir pumps water from the reservoirs to the Water Treatment Plant (WTP) on Spring Lane. Following the treatment process, water flows to a clearwell, and then pumped into the distribution system. Well #1 pumps into the clearwell while Well #2 pumps directly into the distribution system in Ferry Road. Bartlett Spring Pond is a spring fed pond located north of the Water Treatment Plant.

This Watershed Protection Plan focuses on the three reservoirs that provide approximately 80% of Newburyport's water supply: Indian Hill, Upper Artichoke and Lower Artichoke Reservoirs.

According to FEMA's recent revisions to the Flood Insurance Rate Maps, the concrete spillway elevation at the Lower Artichoke Reservoir Dam is 3 feet below the Flood Zone AE Elevation (100-year floodplain), which highlights the vulnerability of the water supply. Storms slightly greater than the 10-year storm have the potential to cause the Merrimack River to back up into the reservoir and contaminate it with brackish saltwater from the incoming tide and potentially other contaminants from the river itself.

There are a variety of issues confronting the City: the need for improved watershed protection, improved resiliency against sea level rise and climate change impacts, and strengthening of the Lower Artichoke Dam. This watershed protection plan incorporates watershed management, by-law development, dam improvements, and options for infrastructure redundancy to provide holistic options for addressing the issues facing the City's water supply system. A summary of the recommendation in the report, organized by topic, is provided below.

Interconnections

- Coordinate with West Newbury regarding the potential groundwater source off Dole Place.
- Continue working with the City of Amesbury for an emergency interconnection.
- Consider a potential interconnect with Salisbury to provide added flexibility under an emergency situation.

Demand Management

- Complete a buildout of the service area in Newbury to determine the anticipated need. As the service area is limited to Old Town and Plum Island, water usage for Newbury may not increase as much as projected.

- Reassess the agreement for sale of water with West Newbury. The projections are currently based on the existing agreement language that states that Newburyport can sell up to 175,000 gpd to Newbury. Typically, the overall volume of water sold to West Newbury is less than this amount over the course of the year. Also, Newburyport should work into the agreement a requirement for West Newbury to establish water supply protection regulations for the surface water supply.

Regulatory Revisions

- Review the current Water Use Restriction Ordinance and update it to be in conformance with updated model language from MassDEP.
  - Providing a definition of Non-essential Outdoor Water Use that includes examples and exceptions.
  - Including a designee of the Board of Water Commissioners who can declare a State of Water Supply Conservation or State of Water Supply Emergency. This avoids any delay in imposing restrictions until the next scheduled board meeting.
  - Prohibiting outdoor watering at a minimum, between 9AM and 5PM. This is consistent with good irrigation practices which seek to avoid irrigation during periods of high evapotranspiration.
  - Removing "odd/even day watering" and replacing it with a limitation on the allowed number of days per week of watering. No more than two days per week is recommended, with the actual number of days and particular hours (outside the 9 am to 5 pm window) to be determined by the Board of Water Commissioners or its designee.
  - Adding an option that would require private well users to abide by restrictions imposed by the community or water district.
  - Adding a definition of a State of Drought and an option to institute additional restrictions during a declared drought.
  - The addition of an optional section at the end of the bylaw that regulates the use of in-ground lawn and garden sprinkler systems.
- The City of Newburyport has adopted a regulation prohibiting the use of pesticides containing glyphosate on City-owned properties, but not for private properties. As part of its coordination efforts with West Newbury and Newbury, the City should encourage these communities to adopt a similar regulation.
- The City should continue to incorporate regulatory changes required through the EPA Municipal Separate Storm Sewer System (MS4) general permit, including encouraging infiltration, Low Impact Development practices, and BMPs that are designed to remove nutrients.

West Newbury Coordination

- Coordinate with West Newbury to establish surface water protection bylaws Newburyport should be designated as a concurrent reviewer by West Newbury and Newbury of any project proposed within Zone A of the watershed.

- Work with West Newbury to implement a manure management bylaw to provide some oversight for horse owners. An example bylaw from the Town of Easton, MA is provided in Appendix K. Additional resources on horse stable and manure management can be found here: https://extension.psu.edu/horse-stable-manure-management.

Recreation Uses and Public Outreach

- Newburyport should continue to coordinate with Essex Greenbelt to ensure proper use of the trail systems to minimize impacts to the watershed.
- Horseback riding along the Indian Hill Reservoir service road should be strongly discouraged, as the waste is difficult to manage and is a direct source of pollutant loading to the reservoir.
- Pet waste eliminator stations should be installed (which should include pet waste clean-up signage) at the unpaved boat launch area at the Upper Artichoke Reservoir in Newburyport and the gated entrance to the access road to Indian Hill Reservoir in West Newbury. Trash pickup/bag refilling should be routinely conducted at these locations.
- Signage should be posted at the gated entrance to the service road and at the boat ramp regarding horseback riding and pet waste clean-up.
- Prepare a recreational management plan to control public access to the reservoirs that would include inspections, enforcement, and public education.

Roadway improvements

- Future design considerations for the roads adjacent to the reservoirs (specifically, Moulton Street along Indian Hill Reservoir and Turkey Hill Road and Rogers Street along the Upper Artichoke Reservoir) should include options to pull the roadway edge away from the reservoir embankment, superelevate or bank the roads away from the reservoirs, install swales, guardrails, and riprap to help address roadway erosion issues and install structural best management practices to pretreat stormwater.
- Deicing practices should also be assessed, as chlorides can negatively impact the drinking water quality and sand can cause sedimentation and carry other pollutants into the reservoirs. A low or no salt zone should be considered for the roadways that directly abut the reservoirs and their tributaries.
- Other roadways within the watershed should be monitored for similar erosion and pollution issues and BMPs implemented where necessary.

Land Acquisition

- Newburyport should continue to work with landowners for right of first refusal, gift, or purchase for priority lands within the watershed. Newburyport should continue to work with local boards and private land trusts, such as the Essex County Greenbelt Association, to pursue land acquisition. In order to fund acquisitions when properties become available, Newburyport should consider establishing an annual budget line item for purchasing land and development rights for watershed protection purposes.

The City can also seek grant opportunities for land acquisition through:

- the Massachusetts Division of Conservation Services (DCS)
- the Drinking Water Supply Protection Grant Program
- Massachusetts Land and Water Conservation Fund Grant Program
- Local Acquisitions for Natural Diversity (LAND) Grant Program
- Community Preservation Act

- Establish an advisory Watershed Protection Committee that includes representative from Newburyport, West Newbury and Newbury. The committee could provide support to the Newburyport DPS Water Division with review of proposed developments within the watershed, coordinate on opportunities for land acquisition, and assist with outreach to the public.

- Newburyport could consider assigning water supply protection duties to a current staff person or a new staff person to conduct watershed inspections and water quality testing, conduct public outreach including outreach to schools, watershed groups, and local boards. Much of this effort is similar to the duties performed by the Engineering Department's Stormwater Engineer for the NPDES MS4 Permit compliance work. This staff person could also be responsible for conducting outreach to the watershed property owners, reviewing land management plans (e.g, SWPPPs or CNMPs) and permit applications, pursue grant opportunities, perform watershed inspections, and act as a liaison with West Newbury and Newbury for watershed protection.

Wildlife and Waterfowl

- The City should continue to monitor the watershed for the presence of beaver activity and continue to take the appropriate measures if excessive beaver activity that may pose a threat to the water supply is detected.
- As recommended in the 2016 AECOM Newburyport Reservoir Water Quality Study Report, total phosphorus load from waterfowl, including inputs from resident and migratory birds, was estimated in the model due to lack of site-specific waterfowl usage data. It was assumed that waterfowl usage was relatively low at the four surface water reservoirs. A survey of the actual waterfowl population would help to update the model with site-specific data in order to more accurately represent the contribution of phosphorus loading that can be attributed to the presence of waterfowl. Weekly counts are recommended for a one year period. Signage discouraging duck feeding should be posted in the vicinity of Upper Artichoke and Indian Hill Reservoirs. The City should also discourage waterfowl nesting. If nest removal is necessary, a Federal depredation permit from the U.S. Fish & Wildlife Service is required for migratory bird.

In-Lake Monitoring and Management

- The limnologist provided recommendations for sampling in their January 2021 report (see Appendix E). The sampling recommendations are reiterated here, however, the

January 2021 report should be reviewed for sampling locations and frequency. This data collection and analysis is important in identifying potential sources of pollution, identifying a potential an algal bloom and can be used to track progress on watershed management.

- In-reservoir monitoring will occur in the deep spot of each reservoir as soon as practicable after ice-out and monthly from mid-May through mid-October. After mid-October, monitoring should continue monthly until the reservoirs freeze. It is estimated that this will result in 8 reservoir monitoring events at four (4) locations over the course of a typical year. These data can be used to assess the variability of water quality in the reservoirs, detect seasonal changes and identify water quality conditions that may support future cyanobacteria blooms. Locations and a schedule are provided in the January 2021 report. Every other reservoir sampling event will include the collection of a duplicate sample at a randomly selected station/depth. In reservoir monitoring will also include observation of the reservoirs for cyanobacteria blooms and contingency phytoplankton identification and toxicity testing.
- Tributary monitoring will be conducted three times each year at a minimum. Monitoring will target three (3) separate runoff events roughly coinciding with spring, summer and fall depending on precipitation patterns. Since flow in many of the small tributaries is primarily storm related, monitoring will occur as soon as practicable after a rainfall of at least 0.25 inches or a period of snowmelt. One event will occur in spring prior to leaf-out. The second event will occur in the mid-summer and the third event will occur in the mid-fall. Typically, dry weather events would be an additional part of a tributary monitoring program however, observations of the tributaries around the reservoirs suggest most are intermittent and only flow when there is rainfall. Sample analyses will be performed by City of Newburyport, Alpha laboratories or the UNH LLMP lab in Durham, NH. This monitoring is expected to be shore based with grab sample collection. Locations and a schedule are provided in the January 2021 report.

- Aquatic vegetation in the reservoirs should continue to be monitored, and the limnologist should be consulted for in-lake recommendations. Results of the continued surveys should be compared to the results of the 2015 aquatic vegetation survey and vegetation management should be considered if invasive species densities appear to be noticeably increasing.

Public Education and Outreach

The development of a public education program for landowners, especially those that abut the reservoirs, will help to address and mitigate impacts within the watershed. The program could focus on effective agricultural BMPs, fertilizer applications, pesticide management, and septic system maintenance for residential landowners.

Outreach to landowners, residents, farms and users of the public lands within the watershed is recommended. The City’s goal is to provide information on the watershed, the water quality concerns and the steps that the public can take to better protect the watershed and the reservoirs. Target audiences include:

- Essex County Greenbelt Association and recreational users

- Recreational users of Newburyport's watershed lands
- West Newbury residents and property owners within the watershed
- Newbury residents and property owners within the watershed
- Newburyport residents and property owners within the watershed

Outreach - BMPs

Work with landowners to install BMPs appropriate to the use of the property. As there are multiple farm parcels adjacent to the reservoirs, there are several resources available to farmers to make water quality improvements at their properties. The NRCS, under the United States Department of Agriculture (USDA) has Best Management Practices (BMPs) for farming and agriculture. See Appendix I for resources. The City should continue to work with agricultural and farming operations within the watershed to further reduce agriculture-related pollution by implementing such measures as:

- Installing fencing to separate livestock from reservoirs and their tributaries. Fencing should be installed a minimum of 100 feet from the banks of rivers, streams, water bodies, and other wetland resource areas.
- Planting buffer zones to the reservoirs and their tributaries
- Installing structural BMPs, such as:
    - water treatment residuals (WTRs) for enhanced phosphorus uptake
    - water quality swales
    - sedimentation basins
    - covering of potential pollutant sources, such as manure piles
- Instituting BMPs for herbicide and pesticide use, including:
    - Selecting optimum herbicides and fertilizers
    - Developing spill response plans for pesticide and fertilizers
    - Developing standard procedures for application (do not spray/apply near waterbodies or waterways or near where runoff enters a waterbody or waterway, do not apply herbicides/fertilizer to saturated or wet soil)
    - Retaining and reusing application equipment rinse water
    - Reading and following application instructions
    - Conducting soil sampling and testing
- Addressing stormwater runoff through farming controls, such as conservation tillage farming, erosion control, or vegetative buffer strips
- Encouraging farmers within the watershed to develop NRCS Comprehensive Nutrient Management Plans may be appropriate for livestock operations in Massachusetts. More information is available at: http://www.nrcs.usda.gov/wps/portal/nrcs/main/ma/technical/ecoscience/nutrient/.

Climate Change/Resiliency Recommendations

Options for keeping the reservoir water cooler include:

- Dredging to increase water depth. Dredging is a useful option for removal of nutrient and other pollutants that have settled on the reservoir floor; however, dredging is not anticipated to have a significant impact on the reservoir temperature as the amount of material required to be removed to achieve a reservoir depth to make a difference in the temperature would not be technically or economically feasible.
- Increasing the height of the reservoirs by increasing the height of the Lower Artichoke Dam. This option would require the City to acquire additional land for the construction of the dam and for the taking of property for reservoir use (accounting for the land proposed to be covered by water with the increased reservoir height). This option would require significant coordination with adjacent landowners and significant environmental and dam-related permitting. Regulators have been reluctant to permit increases in dam heights for storage increases.
- Adding aerators to the reservoirs can increase the movement of the water in the reservoirs and decrease the temperature. Added aeration may also result in increases evaporation.
- Potential innovate options include installation of floating solar panels, which can help shade the reservoir and provide a potential revenue source, or floating wetlands could provide some shading of the reservoir and uptake nutrients to help address algal blooms.

These options would have to be further assessed to determine which are feasible and offer the highest value for the cost.

Dam Maintenance

Implement maintenance recommendations from the 2020 Inspection/Evaluation Report for Lower Artichoke Reservoir Dam, Upper Artichoke Reservoir Dam, and Indian Hill Reservoir Dam & Dikes.

Lower Artichoke Dam Improvements

The Lower Artichoke Reservoir Dam is susceptible to backflow from the Merrimack River, and as the only existing intake for the three surface water reservoirs is within the Lower Artichoke Reservoir, a backflow event could compromise the use of 80% of the City's water supply. Performing dam maintenance and preparing for emergency protection situation are strongly recommended.

- Minimizing the length of the Lower Artichoke Reservoir Dam embankment is recommended, whether or not the embankment height is increased. This would involve extending the embankment in line with the spillway to higher ground to the east and west.
- Use a shorter-term method to protect the Lower Artichoke Reservoir spillway from overtopping during a backwater event, such as large sandbags (Super Sack) or a

water filled dam (AquaDam). This includes construction of access to allow equipment to place these materials when needed.

- While more costly, it is recommended the Lower Artichoke Dam be raised over the Upper Artichoke as major repairs are needed at Lower Artichoke Dam regardless if it is raised and improvements would protect both the Lower and Upper Artichoke Reservoirs and the existing raw water intake. It should be noted that these options only increase the embankment and add a crest gate; they are not proposed to increase the normal reservoir elevation.

Redundant Raw Water Transmission Line

Seven alternatives were evaluated for potential raw water transmission mains that could supply the WTP with water directly from the Indian Hill Reservoir or the Upper Artichoke and Indian Hill Reservoirs. Based on the evaluated criteria, Alternative 6, which follows roadways from Indian Hill Reservoir to the Upper Artichoke Dam, and then crosses the dam and continues adjacent to the east side of the Lower Artichoke Reservoir, is the recommended alternative based on the following:

- Alignment is primarily within existing roadways, which eliminates the need for easements, reduces maintenance costs associated with cross county alignments, and reduces potential wetland impacts.
- A pump station at the Indian Hill Reservoir will be required but this will allow for improved operational flexibility and reliability in the event that the Lower Artichoke Pump Station is unavailable.
- Access to the Upper Artichoke Reservoir would also be possible for flexibility to utilize any one of the three reservoirs. Additional evaluations of pump modifications or pipeline elevations will be required during detailed design to confirm the ability to pump directly from Upper Artichoke Reservoir.

2016 Newburyport Reservoir Water Quality Study Report

Additional recommendations from the Newburyport Reservoir Water Quality Study Report, March 2016, prepared by AECOM, are still valid and are reiterated below.

- **Shoreline Stabilization/Erosion Control at Reservoir Access Points**
  Revegetating reservoir access areas with native vegetation is recommended to improve areas eroded due to foot traffic and high water, as soils entering the pond can include associated phosphorus.

  The Upper Artichoke Reservoir public access area located to the east of the Plummer Spring Road/Middle Street bridge (sampling Site SW-1) is particularly eroded and should be immediately addressed.

  Signage is recommended to help prevent additional erosion:
    - Educational signage regarding the presence of erosion
    - Signage redirecting foot traffic to designated trails only.

- **Coordination with Maple Crest Farm**
  Direct coordination with Maple Crest Farm on Moulton Street in West Newbury is strongly recommended to address their current operations, including leaf compost

bag disposal near the southern shoreline of Indian Hill Reservoir and other land use activities that have the potential to cause phosphorus loading to the reservoirs. Installation of infiltration BMPs in this area is recommended.

- **Conduct a Detailed Watershed Inventory**
  A watershed inventory is recommended to identify specific sites throughout the watersheds that are currently contributing phosphorus to the reservoirs. The effort should include an estimation of the nutrient contribution from each site, the potential solution and a cost estimate. The identified sites would then be prioritized based on phosphorus contribution and technical and financial feasibility.

  The results of the inventory would comprise a critical piece of the watershed-based plan described below.

- **Develop a Watershed-based Plan**
  A watershed-based plan should be prepared in order to be eligible for Section 319 grant funding, as described in Section 5.0. The plan should follow the EPA recommended format, which includes the following nine elements (from MassDEP, 2015):

  Impairment: An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan (and to achieve any other watershed goals identified in the watershed-based plan), as discussed in item (b) immediately below.

  Load Reduction: An estimate of the load reductions expected for the management measures described under paragraph (c) below (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time).

  Management Measures: A description of the non-point source (NPS) management measures that will need to be implemented to achieve the load reductions estimated under paragraph (b) above (as well as to achieve other watershed goals identified in this watershed-based plan), and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan.

  Technical and Financial Assistance: An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan. As sources of funding, States should consider the use of their Section 319 programs, State Revolving Funds, USDA's Environmental Quality Incentives Program and Conservation Reserve Program, and other relevant Federal, State, local and private funds that may be available to assist in implementing this plan.

  Public Information and Education: An information/education component that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the NPS management measures that will be implemented.

  Schedule: A schedule for implementing the NPS management measures identified in this plan that is reasonably expeditious.

  Milestones: A description of interim, measurable milestones for determining whether NPS management measures or other control actions are being implemented.

Performance: A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether this watershed-based plan needs to be revised or, if a NPS TMDL has been established, whether the NPS TMDL needs to be revised.

Monitoring: A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item (h) immediately above.

Most of these elements have been addressed in the 2016 report and this report and could be included in the watershed plan, including the monitoring results, management recommendations, and potential funding sources. An implementation schedule and description of milestones will need to be developed and included in the plan. A plan for conducting a watershed inventory to identify specific sources of phosphorus (as described above) should also be included.

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SECTION 1

Section 1 Introduction

1.1 Background

The majority of the drinking water for the City of Newburyport is sourced from three interconnected surface reservoirs: Indian Hill, Upper Artichoke, and Lower Artichoke. The raw water intake is located at the lowest of the three reservoirs, the Lower Artichoke Reservoir. Newburyport also supplies water to West Newbury and portions of Newbury. The watershed for these reservoirs extends across all three communities.

Both the Upper and the Lower Artichoke Reservoirs are shallow reservoirs that are highly susceptible to impacts from climate change, particularly increased heat and extended drought conditions. These changing climate conditions, coupled with the shallowness of the two reservoirs, increases the likelihood of algal blooms that could compromise the water supply, as evidenced by conditions during the summer of 2020, when the extended drought period contributed to an algal bloom that quickly overtook the Upper Artichoke Reservoir and extended into the Lower Artichoke Reservoir.

The City has limited options for an alternative water supply should the Lower and Upper Artichoke Reservoirs be compromised. The Indian Hill Reservoir is a deeper reservoir with lower nutrient loading and has the best water quality of the three reservoirs; however, a smaller algal bloom occurred in the Indian Hill Reservoir in October 2020. All three reservoirs are impacted by land uses in their watersheds that contribute to nutrient loading and other threats that impact water quality.

In addition, a significant threat to the Lower and Upper Artichoke reservoirs exists from an increasing likelihood of a storm surge from the Merrimack River. The spillway at the Lower Artichoke dam is 8.75 feet, approximately three (3) feet lower than the FEMA-determined base flood elevation for a 100-year storm of 12.2 feet according to the most recent Flood Insurance Study (FIS) for Essex Country, Massachusetts (250108; Dated July 3, 2012 as Revised July 18, 2018) and Flood Insurance Rate Map (FIRM; Community Panels Number 25009C0108F and 25009C0116F; Effective July 3, 2012).

Backwater from the Merrimack River is expected to exceed the Lower Artichoke Reservoir Dam spillway elevation, and potentially overtop the spillway and contaminate the water supply, for storm events slightly larger than the 10-year frequency storm event. The potential for backwater contaminating the water supply increases with a more significant storm event.

Climate change factors including increased frequency and intensity of storms and sea level rise increases the possibility of overtopping of the spillway and dam embankment from the Merrimack River. Saltwater and contaminant intrusion from the Merrimack River, up the Artichoke River, into the Lower Artichoke Reservoir is an imminent threat to the City's water supply as the only raw water intake from the reservoir system is located within 100 feet of the Lower Artichoke Reservoir spillway. The spillway has been near overtopping a number of times over the past decade and the risk is increasing. The Water Treatment Plant does not have the ability to treat potential contaminants from algal blooms or potential pollutants and brackish water from the Merrimack River that could overtop the dam.

This Plan serves as an update to previous water supply related plans as noted below to include an assessment of resiliency options for the reservoir system to meet the City's goals of addressing climate change impacts on water quality, improve watershed protection, and protect the reservoirs against Merrimack River inflow flooding. The purpose of this Watershed Protection Plan is to document, update and build upon the previous efforts that the City of Newburyport has taken to protect its water supply reservoirs and to identify additional strategies to ensure continued protection of the watershed as the climate changes.

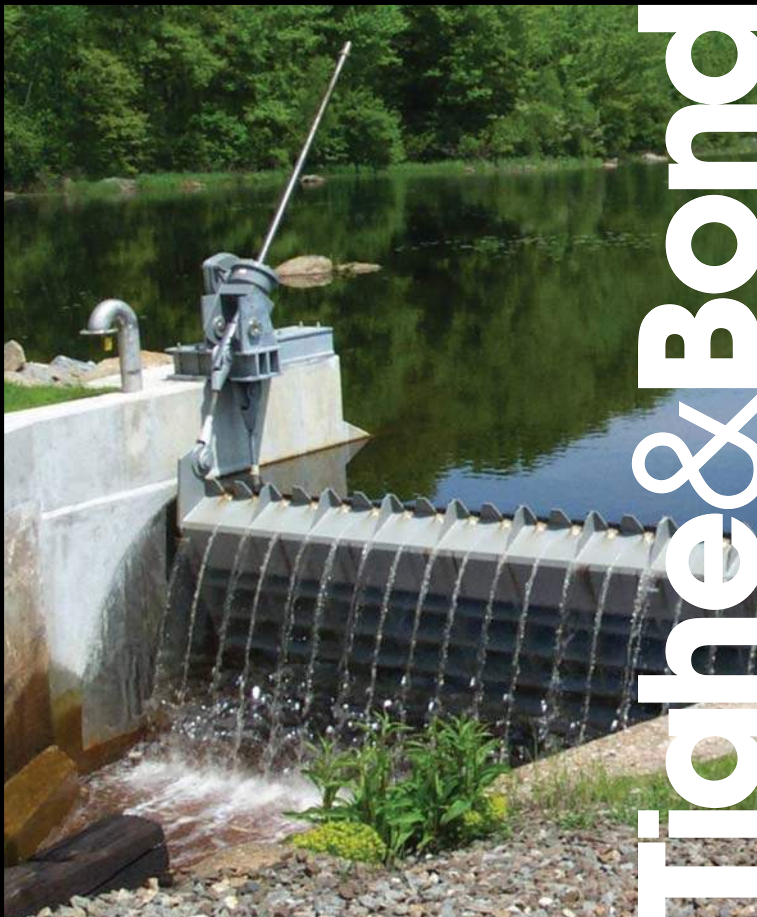
1.2 Previous Reports

Several previous studies have been developed that address watershed protection of the Newburyport water supply system and are referenced within this document. In an effort to streamline this Plan, these previous reports are included by reference to this Watershed Protection Plan. Background information from these reports are incorporated by reference, while recommendations that remain valid are reiterated in this report.

- Water Works Master Plan, City of Newburyport prepared by Fay, Spofford, and Thorndike, November 2002
- Artichoke Watershed Protection Plan prepared by Weston and Sampson, January 2005
- Newburyport Reservoir Water Quality Study Report prepared by AECOM, March 2016
- Water Supply Yield Estimate / Demand Projection Update for Newburyport DPS – Water Division prepared by AECOM, January 2018 (2018 Yield / Demand Update Report)

1.3 Datum

A geodetic datum is a coordinate system with a reference surface that provides known locations to develop surveys and create maps. Different datums exist; and a conversion factor is used to correlate one datum to another. For the purposes of this Plan, elevations are provided in the North American Vertical Datum of 1988 (NAVD88). This is the same datum used by FEMA to define flood levels.



SECTION 2

Section 2
Water Supply and Demand

2.1 Water Supply

The City of Newburyport receives its water from a series of three interconnected reservoirs, a spring-fed pond and two groundwater wells as listed below and as shown on Figure 2-1:

- Indian Hill Reservoir
- Upper Artichoke Reservoir
- Lower Artichoke Reservoir
- Bartlett Spring Pond
- Well #1 off Ferry Road (west of 1-95)
- Well #2 off Ferry Road (east of 1-95)

Water from the Indian Hill Reservoir flows into the Upper Artichoke Reservoir, which in turn flows into the Lower Artichoke Reservoir. The Lower Artichoke Reservoir is the terminal reservoir for the surface water supply system and is where the intake pipe for the raw water pump station is located. A pumping station adjacent to the Lower Artichoke Reservoir pumps water from the reservoir to the Water Treatment Plant (WTP) on Spring Lane. Following the treatment process, water flows to a clearwell, and then pumped into the distribution system. Well #1 pumps into the clearwell while Well #2 pumps directly into the distribution system in Ferry Road. Bartlett Spring Pond is a spring fed pond located north of the Water Treatment Plant.

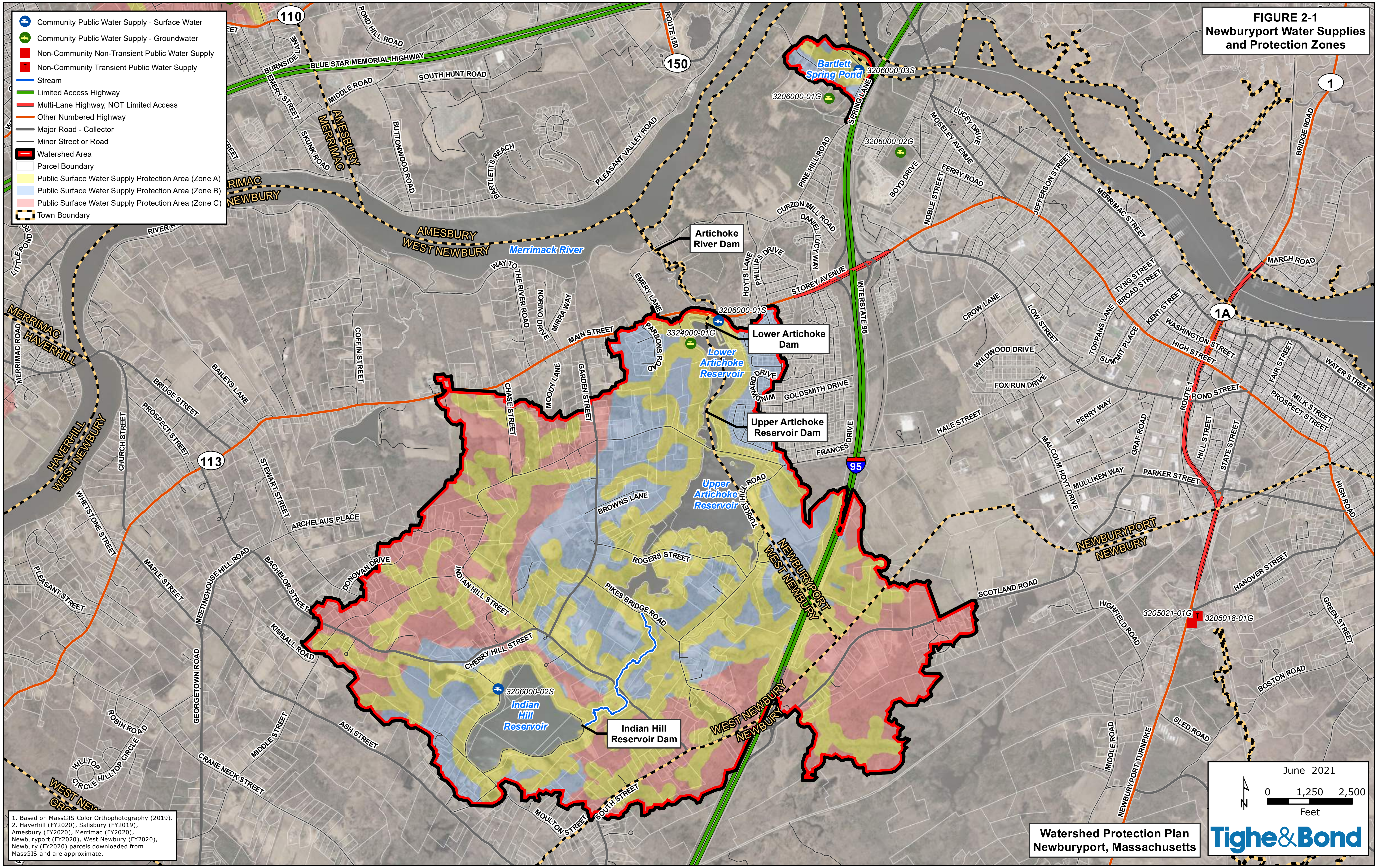
According to the City representatives, the City has sought potential additional public water supply sources within Newburyport and Newbury but no additional viable sources of water were identified.

2.1.1 Surface Water Supplies

The maximum usable volumes for the surface water supplies were presented in the 2018 Yield / Demand Update Report, which used a bathymetric survey performed by CR Environmental, Inc., dated May 2017. The 2018 Yield / Demand Update Report provided maximum usable volumes based on certain criterion and errors in the calculations that were identified during the preparation of this Report. A memo from the City Engineer summarizing these discrepancies is provided in Appendix A. For the purposes of this report, we have used the revised volumes determined by the City.

2.1.1.1 Indian Hill Reservoir

Indian Hill Reservoir, located in West Newbury, is the most upstream reservoir of the reservoir system. It is the largest of the three reservoirs and has a total capacity of approximately 755 MG. This man-made reservoir was completed in 1979 and withdrawal began in 1980. Water from the Indian Hill Reservoir is released through a pentagon-shaped reinforced concrete drop inlet structure located in the reservoir about 30 feet from the gatehouse. This fixed crest, uncontrolled weir structure was rebuilt in 2007 with a top elevation of 61.5 feet and a 48-inch RCP outlet pipe that extends through the earthen dam



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and daylights at the toe of slope downstream. The gatehouse has two intakes. The upper intake is an 18-inch diameter pipe at elevation 49.3 feet and the lower intake is a 24-inch diameter pipe at elevation 38.6 feet.

These intakes discharge water into the Upper Artichoke Reservoir via overland flow through streams and culverts, approximately 6,000 feet to the Pikes Bridge Road cross culvert, which is generally the beginning of the Upper Artichoke Reservoir. See Figure 2-1.

2.1.1.2 Upper Artichoke Reservoir

The Upper and Lower Artichoke Reservoirs are divided by a concrete gravity dam just north of Plummer Spring Road. The Upper Artichoke Dam was reconstructed with a new outlet control structure in 2015. The outlet control is a rectangular concrete structure with vertical stop logs that can adjust the water elevation from the concrete spillway height down to the 24-inch diameter outlet pipe at elevation 2.0 feet. The outlet pipe extends through the dam and into the Lower Reservoir. This allows the City to release water to the Lower Artichoke Reservoir when the water level in the Upper Artichoke Reservoir is below the spillway elevation.

The concrete spillway for the dam approximately 3 feet wide, 135 feet long, at elevation 12.4 feet.

The Upper Artichoke Reservoir extends about 1.5 miles from the dam upstream to Pikes Bridge Road. The reservoir is crossed by two roadways – Rogers Street and Plummer Spring Road. The bathymetric survey used for calculating the usable storage volumes broke out the Upper Artichoke Reservoir into two water body segments with Rogers Street being the interface between the two. The maximum usable storage volume for the Upper Artichoke Reservoir includes both water bodies and is 269 MG.

The portion of the reservoir south of Rogers Street is much shallower and has been prone to more algae blooms. It is separated from the larger portion of the reservoir by a cross culvert under Rogers Street. This culvert has a bar screen but does not have any outlet control.

2.1.1.3 Lower Artichoke Reservoir

The Lower Artichoke Reservoir is the smallest of the three interconnected reservoirs. Its created by a 4,400 foot long earthen dam with an 80 foot long reinforced concrete ogee-shaped weir overflow spillway whose elevation of 8.8 feet is approximately three feet lower than the current FEMA 100-year flood elevation of 12 feet and about 3.6 feet lower than the Upper Artichoke dam spillway. There appears to be a low-level outlet gate to the right side of the spillway but is not operational and not observable. It is unknown if this outlet is discharging reservoir water.

Overflows from the Lower Artichoke Reservoir eventually flow into the Merrimack River. The maximum usable storage volume, based on the City's calculations, is 49.9 MG.

2.1.1.4 Bartlett Spring Pond

Bartlett Spring Pond is the smallest reservoir, located between the Water Treatment Plant and the Merrimack River. During the required pump test conducted during the new source approval process for Bartlett Spring Pond, the firm yield was determined to be 0.27 MGD. The City is approved to use Bartlett Pond as a flood skimming supply, which means that the City cannot draw the reservoir lower than two feet below the spillway. The yield for Bartlett Pond is the result of runoff from its drainage area and springs that feed into the pond.

2.1.2 Groundwater Supplies

The City of Newburyport also operates two groundwater supplies, Well #1 and Well #2. Pumping tests were conducted in the early 2000s to determine the yield of each well. Well #1 has a stabilized pumping rate of 325 gpm and Well #2 has a stabilized pumping rate of 408 gpm. Therefore, the wells have a combined yield of 733 gpm or 1.06 MGD.

2.1.3 Water Supply Interconnections

MassDEP has strongly encouraged the City of Newburyport to develop an interconnection with a neighboring water supplier; however, the City does not currently have any interconnections. An interconnection is an important tool for providing water to Newburyport's customers in the case of an emergency such as a treatment plant shut down, algal bloom, or water main break. Having an interconnection will be more critical as climate change impacts water supply quality and quantity, from increased likelihood of algal blooms to extended droughts. The following is a discussion of neighboring communities and potential for an interconnection with each.

Newbury: The Town of Newbury is served by Newburyport and does not have a separate public water supply; therefore, an interconnect is not possible.

West Newbury: West Newbury's water is supplied by a wellfield located adjacent to the northeast corner of the Lower Artichoke Reservoir. West Newbury also purchases water from Newburyport to supplement their peak demand periods. West Newbury has indicated that they do not currently have additional supply to provide Newburyport so an interconnect is not an option at this time.

West Newbury has been evaluating potential groundwater sources and has performed some preliminary pump testing at a site off of Dole Place. If West Newbury were to develop a water supply at this location, they may have additional water to provide Newburyport in the event of an emergency. The City and West Newbury have had initial discussions regarding this potential water supply.

Groveland: The City previously investigated an emergency interconnection with Groveland via West Newbury. A 2012 hydraulic analysis performed by AECOM determined that up to 273 gpm could be supplied to Newburyport through an emergency interconnection with Groveland via West Newbury. Availability of this volume of water would require modifications to the Groveland system as well as enacting water restrictions. This interconnection option has not been pursued further since the analysis was performed.

Amesbury: Newburyport is actively developing plans for an emergency interconnection with the City of Amesbury. The interconnection would require new connection points on either side of the Whittier Bridge on I-95. During an emergency, a temporary water line would be installed on the bike path to connect Newburyport to Amesbury. The City is currently evaluating more permanent options, such as directional drilling under the Merrimack River or hanging a water main to the bridge's structural members below the roadway deck. The temporary emergency connection is currently undergoing review with MassDOT.

Salisbury: Salisbury is another adjacent community with a public water supply system. Similar to the proposed interconnection with Amesbury, new infrastructure would be needed to cross the Merrimack River to interconnect with Salisbury. Newburyport should consider a potential interconnect with Salisbury to provide added flexibility under an emergency situation.

2.1.4 Firm Yield

The firm yield and safe yield capacities of Newburyport's supply system were calculated as part of AECOM's January 2018 Yield / Demand Update Report and are referenced herein. Tighe & Bond did not update the firm yield or safe yield capacity analyses. As noted in the report, firm yield is a more conservative measure than safe yield and is typically used for water supply planning purposes. A summary of the firm yield capacities of Newburyport's supplies is presented in Table 2-1.

TABLE 2-1
Summary of Firm Yield Capacities of Newburyport's Supply System (source: 2018 Yield / Demand Update Report)

Source	Estimated Firm Yield Capacity (mgd)
Artichoke Reservoir	2.29
Wells No. 1 and 2	0.31
Bartlett Springs Pond	0.27
Total	**2.87**

The Newburyport water withdrawals are authorized through a registration (3206000-01S) for the Artichoke Reservoir system and a permit (3206000-03S) for the Bartlett Spring Pond. Currently, the authorized combined withdrawal rate for the Artichoke Reservoir and Bartlett Spring Pond collectively is 2.2 mgd (the registered volume). A 20-Year Permit Renewal Application was submitted to MassDEP in November 2017. The renewal application requested additional water withdrawal, up to 2.25 mgd, in the final five years of the permit (years 16-20). MassDEP has not yet issued a permit renewal.

2.2 Water Demands

This section summarizes and updates water demand projections for the City of Newburyport and Newbury and briefly discusses the current intermunicipal agreement regarding supplying water to West Newbury.

Newburyport and Newbury:
The most recent water demand projection was provided in the "Water Supply Yield Estimate / Demand Projection Update for Newburyport DPS – Water Division" prepared by AECOM in January 2018 (2018 Yield / Demand Update Report). This memo provides an update to those projections based on updated population values and additional development considerations that were not in place at the time that report was prepared.

Similar to the 2018 demand projection, this analysis examines three categories of future demands: residential, inter-municipal, and non-residential. The analysis also assumes that the City will achieve and maintain the Massachusetts Water Resources Commission performance standards of 65 gallons per capita per day (gpcd) for residential consumption and a rate of 10% unaccounted for water (UAW) through the year 2040. According to the City's annual statistical reports (ASRs) over the last 10 years, Newburyport has averaged approximately 54 gpcd and approximately 8.8% UAW.

Residential Demand

The previous demand projection utilized population projections from the Merrimack Valley Planning Commission's (MVPC) 2016 Regional Transportation Plan (which projected a population of 17,474 people in 2020, 17,375 in 2030, and 18,673 in 2040). We compared this projection to the latest population projection from the Donohue Institute (which predicts a population of 17,993 in 2020, 18,407 in 2030, and 18,673 in 2040). While both projections have the same 2040 population, the MVPC predicted a decrease from 2020 to 2030 and a sharp increase from 2030 to 2040, while the Donohue Institute predicts a more gradual increase over the entire 20-year period.

Based on the most recent U.S. Census estimate from July 2019, the total population of Newburyport is 18,289, which is higher than the 2020 population in either the MVPC or the Donohue Institute projections. In order to forecast population to 2040, we used the 2019 Census estimate for the 2020 population, and then applied the same growth rates from the Donohue Institute projection to this value to project population to 2040. It was assumed that 100% of the population of Newburyport is served by the water system. Table 2-2 summarizes the population projection data for Newburyport.

TABLE 2-2

Newburyport Population Projection Data

Year	MVPC Projection	% Change	Donohue Institute Projection	% Change	Tighe & Bond Projection	% Change
2020	17,474		17,993		18,289	
2025	17,425	-0.3%	18,213	1.2%	18,510	1.2%
2030	17,375	-0.3%	18,407	1.1%	18,705	1.1%
2035	18,024	3.6%	18,561	0.8%	18,860	0.8%
2040	18,673	3.5%	18,673	0.6%	18,973	0.6%

Newburyport serves the Old Town and Plum Island areas of Newbury. The service area within Newbury is an extension of the Newburyport system and is owned and operated by Newburyport. There are no known plans to expand Newburyport's water supply within Newbury. Based on the data presented in the 2018 Yield / Demand Update Report projection, it appears that the portion of the total population of Newbury served by Newburyport is 42.8%. Similar to Newburyport, the population from the July 2019 U.S. Census estimate for Newbury is higher than the both the MVPC and Donohue Institute projections for 2020. The 2019 U.S. Census estimate is 7,148 people compared to the 2020 projected values of 6,446 from MVPC and 6,673 from the Donohue Institute. Using 7,148 people for 2020, the growth rates from the Donohue Institute projection were applied to forecast population out to 2040. The total population for Newbury was multiplied by 42.8% to forecast the service population. Table 2-3 summarizes the population project data for Newbury. The revised combined population numbers for Newburyport and Newbury are presented in Table 2-4 below:

TABLE 2-3
Newbury Population Projection Data

Year	MVPC Projection	% Change	Donohue Institute Projection	% Change	Tighe & Bond Projection	% Change
2020	6,446		6,673		7,148	
2025			6,696	0.3%	7,173	0.3%
2030	6,171	-4.5%	6,708	0.2%	7,185	0.2%
2035			6,702	-0.1%	7,179	-0.1%
2040	6,680	7.6%	6,680	-0.3%	7,155	-0.3%

TABLE 2-4
2020-2040 Newburyport and Newbury Service Area Population Projections

Year	Newburyport	Newbury (Total)	Newbury (Service Area Population)	Total
2020	18,289	7,148	3,059	21,348
2025	18,510	7,173	3,070	21,580
2030	18,705	7,185	3,075	21,780
2035	18,860	7,179	3,073	21,933
2040	18,973	7,155	3,062	22,036

Similar to the 2018 Yield / Demand Update Report demand projection, the future residential demand was estimated by applying the Massachusetts Water Resources Commission performance standard of 65 gpcd.

Inter-Municipal Demand

The City of Newburyport currently sells treated water to the Town of West Newbury. The City has an agreement with West Newbury, which was executed in 1980 and has remained in effect under the original terms since that time (see Appendix B). The agreement allows for Newburyport to sell up to 0.175 mgd to West Newbury "subject to the availability of such water". This same volume is carried forward and not adjusted when forecasting future inter-municipal demand (i.e. water sold to West Newbury), which is consistent with the 2018 Yield / Demand Update Report demand projection.

Non-Residential Demand

The projections for non-residential demands presented here are consistent with the 2018 Yield / Demand Update Report demand projections, but they have been updated to the most recent employment projections for the Merrimack Valley, presented in Table 3.5 of the MVPC's 2020 Merrimack Valley Regional Transportation Plan (see Figure 2-2). These demand projections were estimated using current employment data from the Massachusetts Executive Office of Labor and Workforce Development and 2040 projections prepared by the Merrimack Valley Planning Commission. More details regarding the methodology for estimating non-residential demand is described in the 2018 Yield / Demand Update Report.

Figure 2-2
Merrimack Valley Employment Projections

Merrimack Valley Employment Projections (Source: MassDOT)

Community	2000	2010	2020	2030	2040	% Change 2010-2040
Amesbury	4,777	5,312	5,802	5,838	5,910	11.3%
Andover	34,262	26,579	33,417	33,621	34,038	28.1%
Boxford	910	1,260	1,183	1,190	1,205	-4.4%
Georgetown	2,433	2,658	2,656	2,672	2,705	1.8%
Groveland	1,098	913	1,094	1,101	1,115	22.1%
Haverhill	19,163	21,647	23,645	23,790	24,084	11.3%
Lawrence	23,631	26,296	28,724	28,899	29,257	11.3%
Merrimac	957	877	958	964	976	11.3%
Methuen	14,172	18,296	18,605	18,719	18,951	3.6%
Newbury	1,142	1,735	1,640	1,650	1,670	-3.7%
Newburyport	10,155	12,296	12,480	12,556	12,712	3.4%
North Andover	19,274	20,568	21,683	21,815	22,085	7.4%
Rowley	2,399	2,556	2,618	2,634	2,666	4.3%
Salisbury	2,774	3,498	3,406	3,427	3,470	-0.8%
West Newbury	705	883	882	887	898	1.7%
TOTAL	**137,852**	**145,374**	**158,793**	**159,762**	**161,742**	**11.3%**

Additional Future Demands

The 2018 Yield / Demand Update Report demand projection listed several future development projects for which demands were forecasted and included in the demand projections. Residential and non-residential demands were included for the following development projects:

- Waterfront West (combination of residential and non-residential demands – 100 housing units plus 100-room hotel and 20,000 sq. ft. of retail development)
- National Grid (25 housing units)
- 40R District (540 housing units)
- Turkey Hill Farm (11 housing units)
- "Common Pasture" (Off Hale Street) (17 housing units)
- Business and Industry Park (1,000,000 sq. ft. expansion)

Based on discussions with Andrew Port, City Planner, these future developments are still projected to occur, although it is anticipated that only 2/3 of the 40R District housing units will actually be built, so in our demand projections, we reduced the number of housing units for the 40R District project to 360 housing units. We have not made any other modifications to these demand projections or the timing of when these developments will impact the demand.

One additional future redevelopment was considered: the potential addition of 200 apartments in the Storey Avenue Shopping Area. This area is being considered for rezoning for mixed use. The assumed redevelopment would increase the residential uses in the area while maintaining the commercial uses. Using an average household size of 2.23 persons per household, which comes from the most recent U.S. Census estimate

(July 2019) for Newburyport, the increased demand from these apartments would be 0.029 mgd (200 apartments x 2.23 people per apartment x 65 gpcd). The influence of this additional demand was assumed to begin in the year 2035. Table 2-5 summarizes the updated future demand projections.

TABLE 2-5
Future Demands Resulting from Specific Development Projects

Development	Type of Unit	Number	Water Demand (gallons/day)	Water Demand (MGD)
Residential				
National Grid	Housing Units	25	3,624	0.004
40R District	Housing Units	360	52,182	0.052
Turkey Hill Farm Area	Housing Units	11	1,594	0.002
Jere Myette Fields	Housing Units	17	2,464	0.002
Storey Avenue Shopping Area	Apartments	200	28,990	0.029
Waterfront West	Housing Units	100	14,495	0.014
Total Residential Demand			**103,349**	**0.103**
Non-Residential Demand				
Business & Industry Park	Industrial (sf)	1,000,000	75,000	0.075
Waterfront West	Hotel Rooms	100	11,000	0.011
Waterfront West	Retail Development (sf)	20,000	1,000	0.001
Total Non-Residential Demand			**87,000**	**0.087**
TOTAL			**190,349**	**0.190**

Other Demand Considerations

The previous demands projections also considered unaccounted-for-water (UAW) and treatment plant processing loss. These additional demands were estimated based on a percentage of the total system demand. For UAW, the Massachusetts Water Resources Commission performance standard of 10% was applied. The treatment plant processing loss is estimated at 5%, based on past historical data

Updated Demand Projections

Based on the above considerations, our updated demand projections are presented in Table 2-6. Compared to the 2018 demand projection, the updated demand projections are approximately 0.3 mgd higher at 2.75 mgd, due primarily to the increase in baseline population throughout Newburyport and Newbury. It should be noted that industrial water need vary greatly depending on the type of industry. Depending on what businesses or industries look to site their facility in the park, the water needs may be much greater.

Table 2-7 presents the demand projects using an residential gallon per capita rate of 55 rgpcd, which is closer to Newburyport's 10-year average of 54 rgpcd. Using this value for residential water usage, the demand in 2040 would be 2.38 mgd.

The 2018 Yield / Demand Update report also presented a revised estimated yield of the reservoir system. The total available supply from Newburyport's supply sources, as presented in the report, is 2.87 mgd, which includes the Artichoke Reservoir system, Bartlett Spring Pond, and Wells 1 and 2. The available supply is adequate to support the estimated water average day demand through 2040.

Reduction in Demand

In order to address climate change and resiliency, the City of Newburyport is considering options to restrict development on Plum Island, which is prone to flooding and shoreline retreat. The Plum Island Overlay District (PIOD) was intended to prevent increased buildout on the island but it has not been effective. There are approximately 1,200 homes on Plum Island, roughly one-third are located in Newburyport and two-thirds are located in Newbury. However, the City provides the water and sewer infrastructure on the entire island so planning for changes to both communities is essential.

The City's infrastructure that serves the island is at risk of breakage if there is a breach caused by a flooding event or storm surge. Depending on the area of the breach, the potential loss of utility infrastructure could disrupt or shut down the utility network and impact areas of the community beyond the site of flooding.

As Plum Island is at high risk for impact from sea level rise and storm surge, a retreat of development is possible. Should a retreat of the Island occur at some point in the future, reduction in residences would result in a reduction in demand of 0.174 MGD. This is not anticipated to occur in the near term.

Private irrigation wells may reduce the demand on Newburyport's public water supply system during peak usage periods. With the potential for extending drought conditions, more demand may be placed on the public water supply system for irrigation needs. However, encouraging private irrigation wells is not recommended as private wells may also draw from the same source that feeds the public water supply source and removing this water use also reduces revenue. Additionally, Newburyport would have less control over enforcing water restrictions on private irrigation well owners during drought conditions.

Conclusion

The City has adequate supply to serve the current system needs, and the anticipated development, particularly if Newburyport's customer base continues to use less water than the state requirement of 65 rgpcpd. However, there is not much additional water available should an industry with high water demands move into the Business and Industry Park.

In order to better understand the anticipated demand, Newburyport could do the following:

- Complete a buildout of the service area in Newbury to determine the anticipated need. As the service area is limited to Old Town and Plum Island, water usage for Newbury may not increase as much as projected.

- Reassess the agreement for sale of water with West Newbury. The projections are currently based on the existing agreement language that states that Newburyport can sell up to 175,000 gpd to Newbury. Typically, the overall volume of water sold to West Newbury is less than this amount over the course of the year. Also, Newburyport should work into the agreement a requirement for West Newbury to establish water supply protection regulations for the surface water supply.

Also, as the surface water supply is susceptible to water quality concerns, particularly related to algal blooms, it is recommended that City seek options for system redundancy, such as being able to tap directly into Indian Hill Reservoir, establishing an interconnection with a neighboring water supply for emergency use, or establishing a new redundant water supply, for example working with West Newbury on the potential Dole Place well or establishing a new withdrawal point in the Merrimack River and constructing a new treatment plant.

TABLE 2-6
Updated Average Day Demand Projections (High End of Range – based on 65 rgpcd)

Year	Service Population (Newburyport & Newbury)	Residential Average Day Demand (ADD) (mgd)	Non-Residential ADD (mgd)	Inter-Municipal ADD (mgd)	Future Development ADD (mgd)	UAW (mgd)	Treatment Plant Processing Loss (mgd)	Total ADD (mgd)
2020	21,348	1.39	0.539	0.175	0	0.247	0.124	2.48
2025	21,580	1.40	0.538	0.175	0	0.249	0.124	2.49
2030	21,780	1.42	0.537	0.175	0.026	0.254	0.127	2.54
2035	21,933	1.43	0.539	0.175	0.190	0.275	0.138	2.75
2040	22,036	1.43	0.542	0.175	0.190	0.275	0.138	2.75

TABLE 2-7
Updated Average Day Demand Projections (Low End of Range – based on 55 rgpcd)

Year	Service Population (Newburyport & Newbury)	Residential Average Day Demand (ADD) (mgd)	Non-Residential ADD (mgd)	Inter-Municipal ADD (mgd)	Future Development ADD (mgd)	UAW (mgd)	Treatment Plant Processing Loss (mgd)	Total ADD (mgd)
2020	21,348	1.17	0.539	0.075	0	0.210	0.105	2.10
2025	21,580	1.19	0.538	0.075	0	0.212	0.106	2.12
2030	21,780	1.20	0.537	0.075	0.026	0.216	0.108	2.16
2035	21,933	1.21	0.539	0.075	0.190	0.237	0.118	2.37
2040	22,036	1.21	0.542	0.075	0.190	0.238	0.119	2.38

SECTION 3

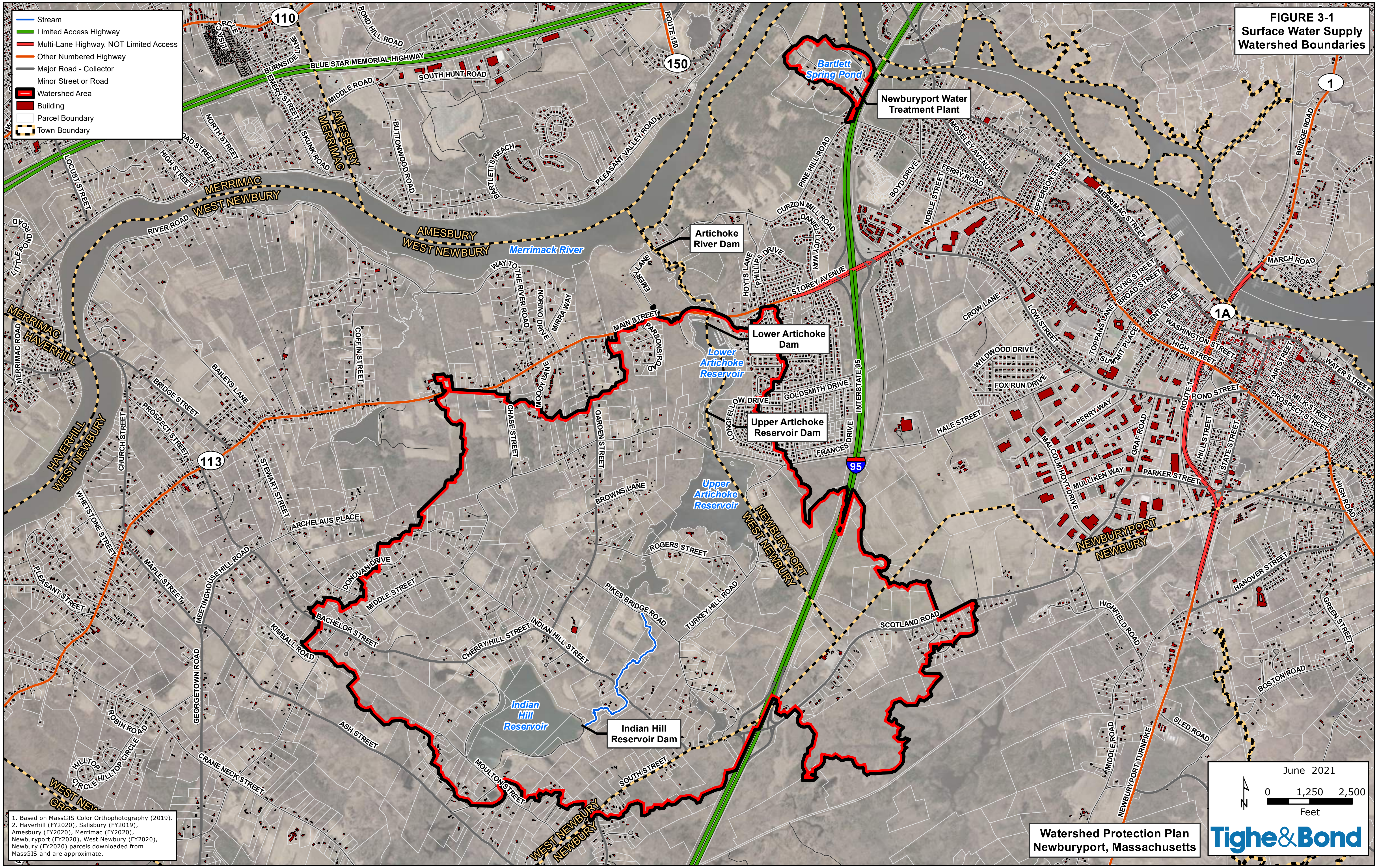
Section 3
Watershed Protection

The Indian Hill Reservoir, Upper Artichoke Reservoir, Lower Artichoke Reservoir are supplied by the same watershed (see Figure 3-1). The combined watershed is approximately 3,700 acres. Land areas in the watershed include parts of West Newbury (75%), Newbury (15%), and Newburyport (10%). The reservoirs were formed from land along the Artichoke River. Uses within the watershed have the potential to impact the quality of water in the reservoirs. Recommended mitigation measures associated with these potential impacts are provided in Section 4.

3.1 Land Use and Potential Impacts

The following list summarizes existing land uses within the watershed along with potential pollution sources. Figure 3-2 depicts land uses within the watershed. Efforts should be made to reduce or eliminate these impacts to prevent future problems:

- On-site septic systems – Since West Newbury does not have public sewer service, all homes in West Newbury are served by septic systems. There are approximately 166 homes located in Zone A of the watershed. The majority of the residences – 115 homes – are located in West Newbury. All homes in Newburyport are connected to public sewer. Population density is low over the majority of the watershed because of residential zoning requirements for large lot dimensions. Large lots provide adequate space for septic systems, which can help reduce environmental impacts.
- Municipal Facilities – municipal facilities within the watershed include Newburyport's Raw Water Pump Station and West Newbury's Wellfield #1 and treatment facility.
- Agriculture – Approximately 10% (378 acres) of the Indian Hill and Artichoke Reservoirs Watershed is designated as agricultural land. This is a reduction from the previous watershed plans, likely in part to the protection and acquisition of land within the watershed by organizations such as the Essex County Greenbelt Association. Land use codes and property ownership were used to identify the different types of agriculture within the watershed.
  - Approximately 180 acres were classified as fields crops/woodlands/nursery
  - Approximately 195 acres were classified as pasture, or were associated with dairy or horse farms
- Residential Fertilizer Use – As noted above there are many residences located within the Zone A. Lush green lawns within the watershed is evidence of fertilizer use at residential properties within the watershed. Improper and excessive use of fertilizers within the watershed is a contributor to nutrient loading within the reservoirs.
- Road Maintenance Shops – The Massachusetts Department of Transportation (MassDOT) has a road maintenance facility on Scotland Road, Newbury.



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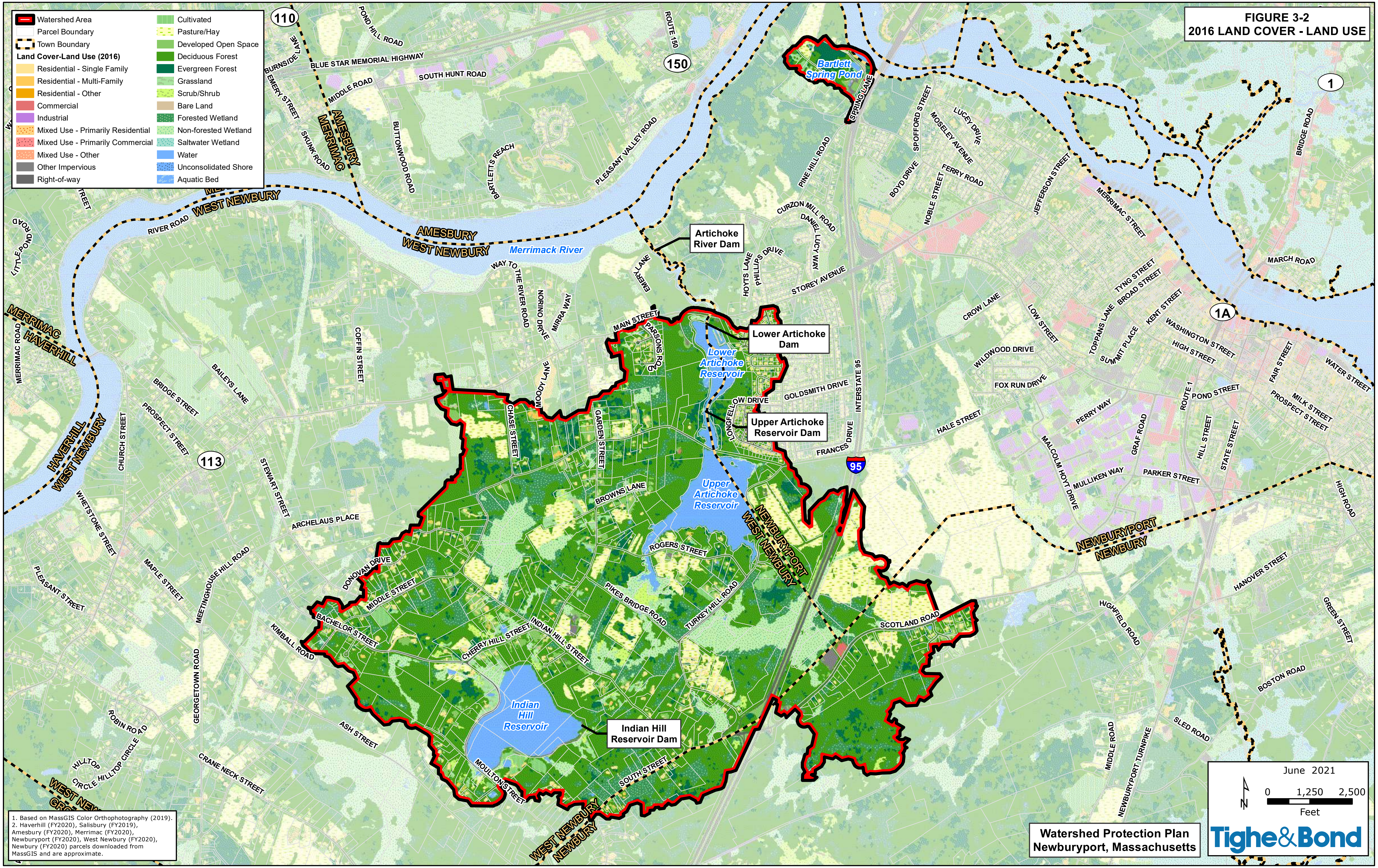


FIGURE 3-2
2016 LAND COVER - LAND USE
Watershed Area
Parcel Boundary
Town Boundary
Land Cover-Land Use (2016)
Residential - Single Family
Residential - Multi-Family
Residential - Other
Commercial
Industrial
Mixed Use - Primarily Residential
Mixed Use - Primarily Commercial
Mixed Use - Other
Other Impervious
Right-of-way
Cultivated
Pasture/Hay
Developed Open Space
Deciduous Forest
Evergreen Forest
Grassland
Scrub/Shrub
Bare Land
Forested Wetland
Non-forested Wetland
Saltwater Wetland
Water
Unconsolidated Shore
Aquatic Bed
Bartlett Spring Pond
Merrimack River
Artichoke River Dam
Lower Artichoke Dam
Lower Artichoke Reservoir
Upper Artichoke Reservoir Dam
Upper Artichoke Reservoir
Indian Hill Reservoir
Indian Hill Reservoir Dam
AMESBURY
WEST NEWBURY
MERRIMAC
HAVERHILL
NEWBURYPORT
NEWBURY
INTERSTATE 95
1. Based on MassGIS Color Orthophotography (2019).
2. Haverhill (FY2020), Salisbury (FY2019), Amesbury (FY2020), Merrimac (FY2020), Newburyport (FY2020), West Newbury (FY2020), Newbury (FY2020) parcels downloaded from MassGIS and are approximate.
June 2021
0 1,250 2,500
Feet
Watershed Protection Plan
Newburyport, Massachusetts
Tighe&Bond

- Salt Storage – Interstate 95 and many local roads pass through the watershed with some running along the shores of the reservoirs. Road salt is a major source of pollution that can easily be carried into water bodies. Runoff containing high sodium chloride concentrations can alter water chemistry and cause health risks. The MassDOT facility on Scotland Road stores sodium-based salt. The Town of West Newbury also uses sodium-based salt. High levels of neither sodium nor chloride have been present in the reservoirs.
- Vehicular Service Station - The MassDOT has a vehicular service station at the maintenance facility on Scotland Road.
- Gasoline Station - The MassDOT has a refueling facility at the maintenance facility on Scotland Road and Salter Transportation has a bus refueling facility also on Scotland Road, Newbury
- Underground Storage Tanks (USTs) – There are no state-regulated USTs within the watershed. However, residential USTs are not regulated by the state and may go undetected. Residential development along Turkey Hill Road creates concerns for USTs for home heating fuel. The MassDOT maintenance facility on Scotland Road in Newbury has one UST at the MassDOT building at the "Road and Maintenance Depot" for refueling vehicles. The privately owned Salter Transportation has two UST for bus refueling.
- Phosphorous Detergents – there is no known use of phosphorous detergents in the watershed. Regulations on sale of phosphate-containing laundry detergent was enacted in the United States in the 1990s and regulations on phosphate containing dish detergent for residential applications was enacted in Massachusetts in 2007. These bans have greatly reduced the phosphorus load from household cleaners. However, some cleaning supplies still contain phosphorous detergents and limited use within residential homes is likely.
- Untreated Stormwater Runoff – In general, there is no detention or treatment of stormwater runoff within the watershed. The runoff from most, if not all, roadways enter roadside swales which eventually enter the reservoirs.
- Hazardous Waste Sites – There are no listed active hazardous waste sites or sites with activity use limitation within the watershed according to MassDEP's online database (https://eeaonline.eea.state.ma.us/portal#!/search/wastesite), viewed on March 9, 2021
- Erosion – Erosion control mechanisms are currently reviewed by the local Conservation Commissions and the Planning Boards when a new development within their jurisdictions is being constructed. Under the U.S. Environmental Protection Agency (EPA) Municipal Separate Storm Sewer System (MS4) general permit requirements, communities are required to develop regulatory mechanisms to control stormwater including developing standards for erosion and sediment control. Contractors should be made aware of BMPs for handling erosion, sediment, and runoff. A summary of stormwater regulations in the watershed communities is provided below.

    - Newburyport is an MS4 community since 2003 and has established a Stormwater Ordinance and implementing Rules and Regulations to address stormwater management in the City
    - West Newbury is a newer MS4 community and is currently seeking funding to develop the required stormwater by-laws and regulations

- Newbury is also an MS4 community, and has enacted a Stormwater Management and Illicit Discharge and Erosion Control Bylaw

Fortunately, other common potential pollution sources are not located within the Artichoke Reservoir Watershed. These include airports, boat yards, dry cleaners, furniture stripping facilities, industrial lagoons, junkyards, landfills, industry/manufacturing facilities, laboratories, machine shops, metal working, photography processing facilities, printing facilities, railroads, sand and gravel mining, septage lagoons or sludge disposal, wastewater treatment facilities, or commercial facilities.

3.2 Open Space / Protected Lands

Protected open space parcels are areas upon which activities are restricted for the purpose of environmental and water supply protection. Parcels receive this designation through easements, conservation restrictions, or other protective mechanisms. Figure 3-3 shows open space and protected parcels within the watershed. These lands can be owned by water suppliers, Conservation Commissions, non-profit land trusts, state agencies, or private parties. The identification of protected parcels within the watershed can help locate future parcels for land acquisition or implementation of deed restrictions. Criteria used to assess the need to protect parcels include distance to water supply or tributary, zoning, slope, soil type, extent of bordering wetlands, wildlife, and proximity to other protected parcels. Protected open space lands within the watershed are owned by the City of Newburyport, the Town of West Newbury and the Essex County Greenbelt Association.

Essex County Greenbelt Association has been actively pursuing acquisition of land within the watershed. They have recently acquired the 23 acre Rogers parcels, and are in process of acquiring 117 Indian Hill Street and a parcel on River Road.

3.3 Zoning

<u>Newburyport:</u>
Zoning regulations play an important role in watershed protection. Based on the current Newburyport Zoning Ordinance, there are two zoning classifications within the portion of the Artichoke Reservoir watershed in Newburyport: Residential One (R-1) and Agricultural/Conservation (Ag/C). Because these zones abut or are close to the reservoir boundaries, activities in these areas are critical to preserving water quality in the reservoir.

Dimensional requirements can impact development density or the number of people per acre. In general, lower density reduces the potential threats to water quality. Residential lots with R-1 must be at least 20,000 square feet.

Ag/C zones are required to be a minimum of 13,000 square feet, except for those uses that include cattle, horses, sheep, goats, dogs, and poultry. These lots must have a minimum of 5 acres. Because runoff form agricultural uses potentially contains heavy loads of nutrients and/or bacteria, efforts should be made to limit or eliminate impacts from these practices. Placing vegetated buffer strips along the edge of the reservoirs to preclude direct contact as well as the elimination of drainage ditches or runoff structures that feed the reservoir can help minimize nutrient loading into the reservoirs. Furthermore, it is recommended that the City develop partnerships with the farmers in the watershed to implement best management practices for water supply protection. In

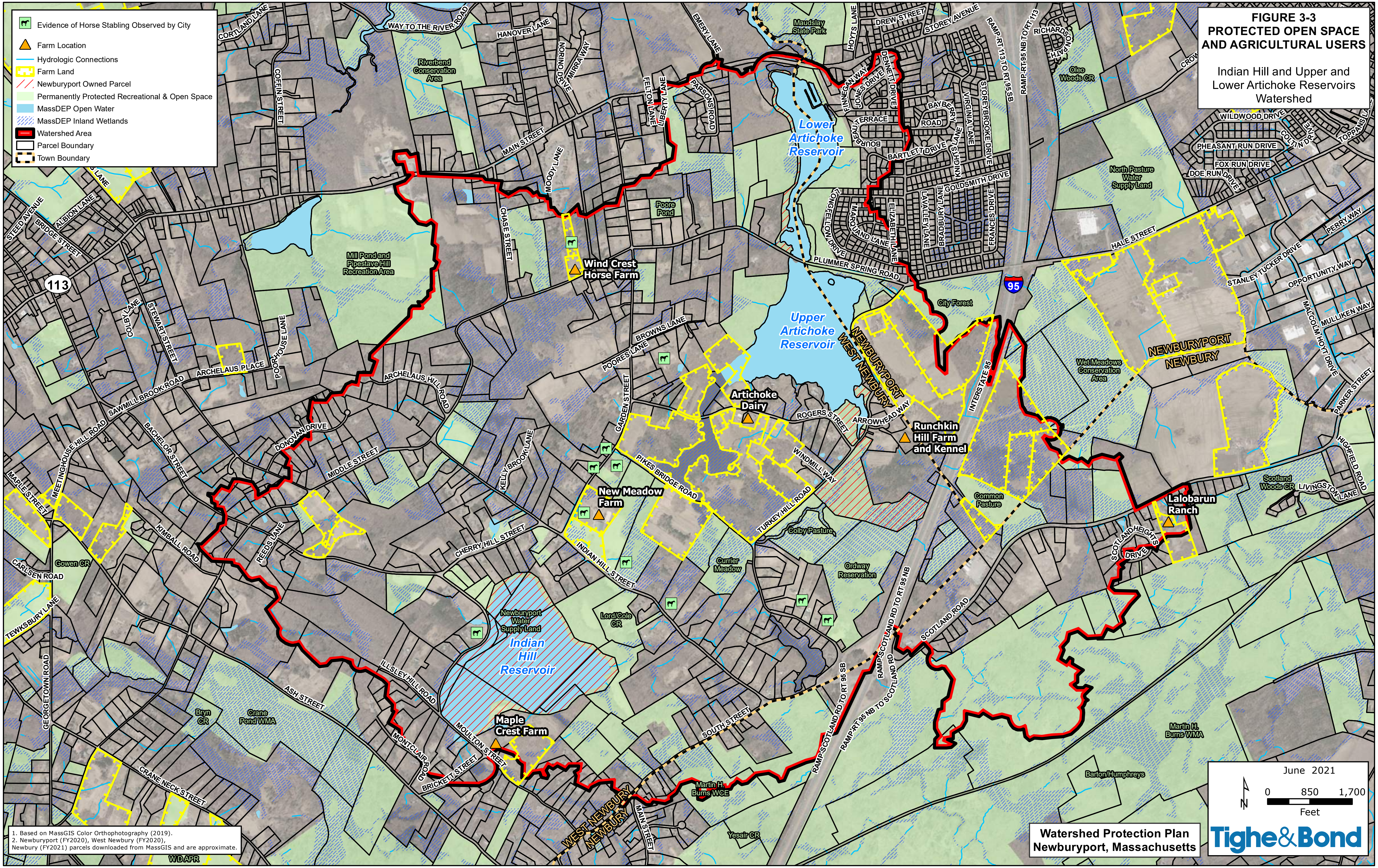


FIGURE 3-3
PROTECTED OPEN SPACE AND AGRICULTURAL USERS
Indian Hill and Upper and Lower Artichoke Reservoirs Watershed
Evidence of Horse Stabling Observed by City
Farm Location
Hydrologic Connections
Farm Land
Newburyport Owned Parcel
Permanently Protected Recreational & Open Space
MassDEP Open Water
MassDEP Inland Wetlands
Watershed Area
Parcel Boundary
Town Boundary
Lower Artichoke Reservoir
Upper Artichoke Reservoir
Indian Hill Reservoir
Newburyport Water Supply Land
Wind Crest Horse Farm
Artichoke Dairy
Runchkin Hill Farm and Kennel
New Meadow Farm
Lalobarun Ranch
Maple Crest Farm
Mill Pond and Pipestave Hill Recreation Area
Riverbend Conservation Area
Maudslay State Park
Poore Pond
City Forest
Oleo Woods CR
North Pasture Water Supply Land
Wet Meadows Conservation Area
Scotland Woods CR
Common Pasture
Colby Pasture
Currier Meadow
Ordway Reservation
Lord/Cole CR
Gowen CR
Bryn CR
Crane Pond WMA
Martin H. Burns WMA
Martin H. Burns WCE
Barton/Humphreys
Yesair CR
WD APR
NEWBURYPORT
WEST NEWBURY
NEWBURYPORT
NEWBURY
WEST NEWBURY
NEWBURY
113
95
June 2021
0 850 1,700
Feet
N
1. Based on MassGIS Color Orthophotography (2019).
2. Newburyport (FY2020), West Newbury (FY2020), Newbury (FY2021) parcels downloaded from MassGIS and are approximate.
Watershed Protection Plan
Newburyport, Massachusetts
Tighe&Bond

addition to education and voluntary efforts, modification of the zoning ordinance may be warranted to address additional protection measures. More information and recommended approaches are presented in the Section 4. These efforts must also be coordinated with West Newbury and Newbury.

Newburyport has also enacted a Water Resource Protection Overlay District, which has been incorporated as Section XIX of the City's zoning ordinance. The District is consistent with MassDEP's guidelines for the protection of surface water resources and follows the regulations set forth in 310 CMR 22.20 B and C, including prohibited uses and uses requiring special permit approval from the Planning Board. The purpose of the District is to:

1. Promote the health, safety, and general welfare of the community by ensuring an adequate quantity and highest quality of water possible for residents, institutions, and businesses in the City of Newburyport
2. Preserve and protect existing and potential watersheds and aquifers for drinking water supplies
3. Prevent temporary and permanent contamination in the Water Resource Protection District
4. Protect the community from the detrimental use and development of land and water within the Water Resource Protection District

A copy of the Water Resource Protection District language is provided in Appendix C.

<u>West Newbury:</u>
The Town of West Newbury has three residential zoning classifications and an industrial zoning classification at the southeastern corner of the Town that are all included within the watershed. The Town also has a business zoning classification, but it is located outside of the watershed. The majority of the residential lots, including those that immediately surround the reservoirs, are classified as RES A, which have a minimum lot size of 80,000 square feet. Some of the residential lots along the northern and western boundaries of the watershed are classified as RES B and RES C, which have minimum lot sizes of 40,000 square feet and 20,000 square feet, respectively.

<u>Newbury:</u>
The portion of the watershed located in the Town of Newbury is zoned Agricultural Residential (R-AG). Dimensional requirements within the R-AG District vary by the type of residential structure as follows:

Single Family Residence	40,000 square feet
Two Family Residence (served by public water supply)	60,000 square feet
Two Family Residence (all other)	80,000 square feet

3.4 Public Access/Recreation

Recreational activities allowed in and around the reservoirs are limited to hiking and fishing. Swimming and boating are prohibited, as well as the use of firearms. Public access impacts in the watershed include vehicular and pedestrian traffic, erosion, trash, domestic animal waste, and unauthorized swimming in the reservoirs. In general, these are low impact activities, but they can create a non-point source of pollution if trails along the edge of the water supply are not properly maintained, which can lead to erosion of soils, or recreational users leave trash behind. Access to lands along the edge of the reservoirs enables domestic animal waste to enter the water supply.

Essex Greenbelt has acquired, and is in the process of acquiring, land within the watershed. Essex Greenbelt has established hiking trails on their properties and provide small parking areas for access. Some trails are used by horseback riders as well. Additionally, some woods paths do exist and are used by local residents and fishermen. There are no public restrooms for recreational activities. Newburyport should continue to coordinate with Essex Greenbelt to ensure proper use of the trail systems to minimize impacts to the watershed.

3.5 Wildlife Management

Farm animals, domestic pets, and wild animals can be carriers of waterborne diseases such as *Giardia*, *Cryptosporidum*, and *Salmonella*. Animal populations to monitor include dogs, horses, cattle, geese, beaver, muskrat, and deer. Forestland comprises about 1,802 acres (46%) of the land within the Upper and Lower Artichoke and Indian Hill Watersheds. Riparian corridors and large wooded lots in the watershed provide wildlife with shelter and access to food and water.

The presence of beaver activity within the watershed has been problematic for the City in the past. The City has worked with the MassDEP and the West Newbury Board of Health and Conservation Commission to allow for the removal of beaver in the watershed. The City should continue to monitor the watershed for the presence of beaver activity and continue to take the appropriate measures if excessive beaver activity that may pose a threat to the water supply is detected.

3.6 Agricultural Uses

In addition to wild animals located near surface waters, farm animals can also impact water quality by contributing additional nutrients and bacteria to the water supply. Farm animals within the watershed include dairy cows at Artichoke Dairy Farm, which abuts the Upper Artichoke Reservoir on Rogers Street, and horses throughout the watershed, one notably located adjacent to Indian Hill Reservoir on Moulton Street. Horseback riders also use trail systems within the watershed. Runoff from these properties during rainfall events and during a spring thaw create concerns due to their close proximity to the reservoirs.

One of the biggest challenges of agricultural activities in the watershed is the potential for excess nutrients from fertilizers and animal waste in the runoff that eventually drains into the reservoirs. Under the right conditions, the presence of excess nutrients can lead to algal blooms, as the City experienced during the summer of 2020.

Agriculture is a significant land use in the watershed and these uses have the potential to cause water quality issues. Areas of concern with agriculture uses include livestock in the reservoirs, pathogen and nutrient contaminated runoff to the reservoirs and their tributaries, use of fertilizers and pesticides for plant cultivation and leaching of nutrients, pathogens, and chemicals to the groundwater that interfaces with the reservoirs.

3.7 In-Lake Problems / Algae Management / Water Quality

Algae growth is a significant potential problem for water quality in the reservoirs. Algal blooms are characteristic of a "eutrophic lake", which indicates that high nutrient levels will compromise water quality. Nutrients enter through runoff from surrounding land or from failing septic systems. Vegetation that dies at the end of each growing season also contributes to increased nutrient loads as well as sediment deposition in shallow water environments. Phosphorus is generally the primary limiting nutrient in northern temperate lakes. Algal growth is typically directly related to phosphorus concentrations, but nitrogen is also a nutrient of concern and should be monitored.

In August 2020, a significant algal bloom broke out in the Upper Artichoke Reservoir and eventually made its way to the Lower Artichoke Reservoir. The situation became so dire that the city hired an engineering firm to design an emergency interconnect to the water system in Amesbury, via the Whittier Bridge. The reservoirs were treated with copper sulfate to control algae growth and fortunately the emergency connection was not necessary.

In October 2020, algae that had been growing in the Indian Hill Reservoir rose to the surface creating a smaller bloom. This is the first known bloom in Indian Hill Reservoir that the city is aware of.

The City started collecting monthly samples in the reservoirs for color, pH, turbidity, alkalinity, and temperature. Testing for bacteria has also occurred to identify sources of pollutants within the reservoirs. Sampling for nutrients (phosphate, phosphorous, nitrate) and collection of depth profile or algae samples has not been conducted on a regular basis. Recognizing that nutrients have a key role in the water quality of the reservoirs, the City sampled for Total Phosphorus (TP), Soluble Reactive Phosphorus, Nitrate as Nitrogen, Ammonia as Nitrogen, and Total Kjeldahl Nitrogen (TKN) in 2015 and again in 2019 and 2020. These analyses are summarized in the October 26, 2020 Water quality summary and discussion of 2020 cyanobacteria blooms memorandum prepared by Don Kretchmer CLM and Ken Wagner PhD CLM and provided in Appendix D.

As noted in the October 2020 memorandum, 2019 and 2020 total phosphorus concentrations in Lower Artichoke reservoir were similar to that observed in 2015 while 2019 and 2020 results for Upper Artichoke were near the upper range observed in 2015. Indian Hill total phosphorus concentrations in 2019 and early 2020 were similar to that observed in 2015 but September 2020 results were the highest observed to date.

The limnologist provided recommendations for sampling in their January 2021 report (see Appendix E). The sampling recommendations are reiterated here, however, the January 2021 report should be reviewed for sampling locations and frequency. This data collection and analysis is important in identifying potential sources of pollution, identifying a potential an algal bloom and can be used to track progress on watershed management.

- In-reservoir monitoring will occur in the deep spot of each reservoir as soon as practicable after ice-out and monthly from mid-May through mid-October. After mid-October, monitoring should continue monthly until the reservoirs freeze. It is estimated that this will result in 8 reservoir monitoring events at four (4) locations over the course of a typical year. These data can be used to assess the variability of water quality in the reservoirs, detect seasonal changes and identify water quality conditions that may support future cyanobacteria blooms. Locations are described in the January 2021 report in Table 3 and Figure 1. A schedule is presented in Table 5 of the January 2021 report. Every other reservoir sampling event will include the collection of a duplicate sample at a randomly selected station/depth. In reservoir monitoring will also include observation of the reservoirs for cyanobacteria blooms and contingency phytoplankton identification and toxicity testing.

- Tributary monitoring will be conducted three times each year at a minimum. Monitoring will target three (3) separate runoff events roughly coinciding with spring, summer and fall depending on precipitation patterns. Since flow in many of the small tributaries is primarily storm related, monitoring will occur as soon as practicable after a rainfall of at least 0.25 inches or a period of snowmelt. One event will occur in spring prior to leaf-out. The second event will occur in the mid-summer and the third event will occur in the mid-fall. Typically, dry weather events would be an additional part of a tributary monitoring program however, observations of the tributaries around the reservoirs suggest most are intermittent and only flow when there is rainfall. Sample analyses will be performed by City of Newburyport, Alpha laboratories or the UNH LLMP lab in Durham, NH. This monitoring is expected to be shore based with grab sample collection. Locations are described in the January 2021 report in Table 4 and depicted in Figure 1. A schedule is presented in Table 5 of the January 2021 report.

Vegetation is another concern for water quality in the Upper and Lower Artichoke Reservoirs. Historically, certain areas of the reservoirs have become clogged with vegetation. Rooted plants within the reservoirs is a sign of eutrophication, increased vegetation in the reservoirs reduces water movement, enhances settling of particles, and the dead plants add to the sediment layer. For a water utility, this decreases the usable volume of a reservoir. Heaviest growth has been in the southwest and northeast corners of the Upper Artichoke Reservoir and throughout the Lower Artichoke Reservoir.

At the Indian Hill Reservoir, the littoral zone, or portion of the lake shallow enough to support rooted aquatic plants, is relatively small, but weeds have formed in the southeast section of the reservoir. Vegetation in the reservoirs should continue to be monitored, and the limnologist should be consulted for in-lake recommendations.

3.8 Spills/Roadway Runoff

The presence of roadways throughout the watershed creates the risk of spills and pollutants from motor vehicles. Traffic volume varies from light, local traffic on state and town roads to heavy traffic on Interstate 95. Service vehicles, including heating oil trucks, are commonly on these roads. The magnitude of spills can range from minor spills from leaking engines to large-scale hazardous waste spills caused by a traffic accident. Any of these spills have the potential to contaminate the water supply.

Stormwater runoff over roadways accumulates deposition from debris, vehicle exhaust, tire wear, accidents, lubricating oils, and deicing operations. These contributing factors can result in increased pollution in stormwater runoff from oils, heavy metals, salts, and other chemicals on the road surface. Street sweeping is an effective way to remove pollutants from roadways so they are not flushed into the reservoirs during storm events. Additionally, there are harmful chemicals present in the pavement from bituminous binder used in hot mix asphalt. However, there is limited information on the impact of the roadway material to water quality.

SECTION 4

Section 4
Recommended Watershed Management Practices

4.1 Regulatory Controls / Ordinance Revisions and Development

Since the watershed is located in multiple towns, a multi-community coordination plan would be mutually beneficial to Newburyport, West Newbury, and Newbury, as all three are served by a common water supply. Protection of the water supply depends on the ability of the three communities to work together and develop a protection plan that establishes regulatory controls for land use activities.

Table 4-1 provides a summary of the different entities and their jurisdictions as they relate to water quality protection.

Table 4-1
Regulatory Responsibilities[1]

Agency	Regulation	Authority
Newburyport Board of Water and Sewer Commission	Waters Act of 1908, Amendment of 1965 to the Act of 1908, 2014 Act Establishing A Board Of Water And Sewer Commissioners in the City of Newburyport	As identified in Sections 2, 3, and 13 of the Waters Act of 1908, the City has rights to waters in the City of Newburyport and West Newbury as either surface and/or groundwater. The City has the right to acquire land to secure water distribution and purity to residents of Newburyport and West Newbury. The Water and Sewer Commission shall be responsible for obtaining the titles for such land. Section 13 authorizes the City to collect damages in the event anyone pollutes the described resource waters or damages any part of the conveyance system.
Newburyport Planning Board and Building Inspector/Enforcement Officer	Section XIX - Water Resource Protection District in the City of Newburyport Zoning Ordinance	The water resource protection district is an overlay district superimposed on the zoning districts. This overlay district applies to all new construction, reconstruction, or expansion of existing buildings and new or expanded uses within the Water Protection Overlay District within the City of Newburyport. The Planning

[1] Public Water Supply (Surface Water) and Water Rights Memorandum, August 19, 2020, Amy E. Kwesell, Esq., KP Law and MassDEP Regulatory Improvements for Reservoirs (see Appendix H)

		Board is responsible for review of Special Permit applications and the Building Inspector/Enforcement Officer is responsible for enforcement.
Newburyport Board of Water and Sewer Commissioners or Mayor	Powers of Cities and Towns, Public Water Supply statutes, G.L. c. 40, §§ 39A – 39G	Section 39G of Chapter 40 provides: "[w]hoever willfully or wantonly corrupts, pollutes or diverts any of the waters taken or held under said sections thirty-nine A to thirty-nine E [public drinking water supply, including reservoirs], inclusive, or injures any structure, work or other property owned, held or used by a town under the authority and for the purposes of said sections, shall forfeit and pay to said town three times the amount of damages assessed therefor, to be recovered in an action of tort…."
MassDEP, Newburyport Board of Water Commissioners	Massachusetts Drinking Water Regulations, 310 CMR 22.00	Under state law and the Massachusetts Drinking Water Regulations, 310 CMR 22.00, MassDEP is the authorized entity for bringing enforcement actions regarding drinking water or quality violations. G.L. c. 21, § 44; 310 CMR 22.01. The City could request MassDEP's assistance in bringing enforcement action under the regulations. Boards of water commissioners of municipalities, any executive officer or agent of such board or of a public institution or water company, and any police officer employed by such suppliers, have the authority to enter any premises, excluding dwelling houses, within the watershed of a public water supply source to determine compliance with the requirements of 310 CMR 22.00. See M.G.L. c. Ill, S.173B. In addition, police officers employed by the above referenced suppliers have all the powers and duties of municipal police officers in the cities and towns served by the supplier. See M.G.L. c. Ill, S.173A.
Board of Health/Health Agent	Public Health statutes, G.L. c. 111, § 162, 167	A local Board of Health may bring an enforcement action pursuant to G.L. c. 111, § 167 for the "protection of sources of water supply" where the deposit of "other matter will corrupt or

		impair the quality of the water or render it injurious to health.”
Conservation Commissions	Wetland Protect Act, G.L. c. 131, § 40	Regulate alteration of wetland resource areas and compliance with the MassDEP Stormwater Standards. MassDEP is currently updating the Stormwater Handbook and the Wetlands Protection Act stormwater regulations in part to provide consistency between federal and state regulations.
USEPA	Federal Clean Water Act Section 404	The federal Environmental Protection Agency (EPA) and the Attorney General are entities authorized to enforce federal drinking water acts.
USEPA	Federal Clean Water Act Section 402(p)	EPA regulates discharges of stormwater from small MS4s in Massachusetts under a NPDES General Permit. Regulated municipalities are required to implement regulations to prohibit illicit discharges into the MS4 system and to regulate construction and post-construction stormwater management from new developments and redevelopments.

Newburyport:
The City of Newburyport has already established a Water Resource Protection District, which has been incorporated into the City’s zoning ordinance. Opportunities to enhance the Newburyport Water Resource Protection District include the addition of nutrient removal requirements through stormwater best management practices within the watershed.

EPA has developed a list of resources for identifying nutrient removal capabilities of various BMPs (https://www.epa.gov/npdes-permits/stormwater-tools-new-england#swbmp). Any new development or redevelopment project occurring within the watershed should include a requirement to implement stormwater best management practices to optimize nitrogen and phosphorous removal.

Additional control would be prohibition of the use of fertilizers or pesticides within the Public Water Supply Protection Zones A and B. Current Massachusetts regulations at 333 CMR 12, provide restrictions for the application of pesticides within the Zone II of a groundwater drinking water source. See Section 4.3 for additional information regarding pesticide regulations and options for the City.

Regulatory control of water resources within the Artichoke Reservoir Watershed is also provided via the Massachusetts Wetlands Protection Act and the Rivers Protection Act. These legislative controls serve to protect water within the Commonwealth for purposes of:

- Public and private water supply protection
- Groundwater supply protection
- Flood control
- Storm damage prevention
- Pollution prevention
- Fisheries protection
- Wildlife habitat protection
- Protection of land containing shellfish

Currently, any activity that involves placement of fill, removal, dredging, or alteration of land within a 100-foot buffer zone around any wetland or within a 200-foot buffer zone of any area surrounding a perennial stream is subject to regulations. Such activities require filing of a Notice of Intent (NOI) with the local conservation commission and the MassDEP before the project can proceed. Compliance with the Massachusetts Stormwater Management Policy is also required as part of the NOI process.

4.1.1 Coordination with West Newbury and Newbury

The majority (approximately 75%) of the Artichoke Reservoir watershed is located with the Town of West Newbury, but the Town has not adopted a Surface Water Supply Protection District or any type of watershed protection bylaw similar to the protections provided under Newburyport's Water Resource Protection District. A draft bylaw has been developed for West Newbury's consideration and is included in Appendix F; however, West Newbury has constraints on staffing and resources to enforce such a bylaw and have yet to prioritize moving forward with the process to enact a new bylaw. The City should continue to work with the Town of West Newbury to formally adopt the Surface Water Protection District bylaw or to modify the existing Groundwater Protection Overlay District bylaw to incorporate surface water protections. Incorporation of regulatory changes required for compliance with the MS4 General Permit should also be considered in the watershed protection laws. Outreach related to the by-law development is included in the outreach plan in Appendix G. Newburyport should be designated as a concurrent reviewer by West Newbury and Newbury of any project proposed within Zone A of the watershed.

West Newbury's current Groundwater Protection Overlay District , which includes the west shore of Lower Artichoke Reservoir, affords some protection to the reservoir, but extension of the land use controls to Zone A and Zone B of the Artichoke and Indian Hill watershed would further improve water supply protection. For the residential areas abutting the reservoirs and their tributaries that are served by septic systems, a public education program and regulation of subsurface disposal systems consistent with Title 5 requirements should be developed. This could include a program to track septic tank maintenance including regular pump outs from residents within the watershed.

All three communities should coordinate to impose restrictions to reduce salt and sand being applied to public and private roads during the winter months. Signs should be posted along roads that receive limited sand and salt applications. Deicing chemicals can alter the water chemistry of the reservoirs, negatively impacting water quality and biodiversity, including macroinvertebrates and microinvertebrates, and potentially contributing to toxic algal blooms. Preparation of erosion control plans as well as road maintenance in the spring and summer, such as street sweeping, debris removal, and pothole repair will reduce pollution and sediment input into the reservoir at road crossings.

As noted in Table 4-1, public water suppliers are on the forefront of enforcing the land use controls in 310 CMR 22.20B. Section 22.20B(7)(a) requires the following:

- a public water system shall conduct regular and thorough inspections of Zones A, B and C to determine and enforce compliance with 310 CMR 22.20B; and
- the public water system shall take prompt enforcement actions against persons violating 310 CMR 22.20B and shall report all such enforcement actions and the results of the regular inspections made during the preceding calendar year to MassDEP in the system's Annual Statistical Report. The report shall include the number and dates of the inspections, the number, nature and outcome of violations found and enforced against by the public water system and the general condition of the watershed at the time of the last inspection.

Regular inspections of the watershed can help identify land uses that are not complying with the drinking water regulations and local zoning controls, as well as identifying changes in the watershed. Information garnered from inspections can be used to update sampling plans and identify public education opportunities and other source protection measures.

If an issue is identified, either through a site inspection or through sampling results, the owner of the property should be identified and Newburyport should reach out to the owner through a visit or call identifying what the concern is, what specific action is needed to remedy the issue, and request for the owner's cooperation and compliance within a specified timeline. This discussion should be followed-up with a letter memorializing the discussion, including the details of the issue, corrective action, and timeline. This letter should be sent by certified mail. Legal counsel should be included for advice. An inspection log, photographs and copies of all correspondence should be assembled for each enforcement case. If the property owner is not responsive, then legal counsel should be consulted for next steps. MassDEP is also a resource for assisting with enforcement actions. A flowchart for enforcement activities is provided in Appendix H.

4.2 Agricultural BMPs

As noted in Section 3, agriculture is a significant land use in the watershed and these uses have the potential to cause water quality issues. Areas of concern with agriculture uses include livestock in the reservoirs, pathogen and nutrient contaminated runoff to the reservoirs and their tributaries, use of fertilizers and pesticides for plant cultivation and leaching of nutrients, pathogens, and chemicals to the groundwater that interfaces with the reservoirs. Agriculture uses include livestock, tree farms, and cropland. The NRCS, under the United States Department of Agriculture (USDA) has released Best Management Practices (BMPs) for farming and agriculture. The City should continue to work with agricultural and farming operations within the watershed to further reduce agriculture-related pollution by implementing such measures as:

- Installing fencing to separate livestock from reservoirs and their tributaries. Fencing should be installed a minimum of 100 feet from the banks of rivers, streams, water bodies, and other wetland resource areas.
- Planting buffer zones to the reservoirs and their tributaries
- Installing structural BMPs, such as:

  - water treatment residuals (WTRs) for enhanced phosphorus uptake
  - water quality swales
  - sedimentation basins
  - covering of potential pollutant sources, such as manure piles
- Instituting BMPs for herbicide and pesticide use, if not otherwise prohibited, including:
  - Selecting optimum herbicides and fertilizers
  - Developing spill response plans for pesticide and fertilizers
  - Developing standard procedures for application (do not spray/apply near waterbodies or waterways or near where runoff enters a waterbody or waterway, do not apply herbicides/fertilizer to saturated or wet soil)
  - Retaining and reusing application equipment rinse water
  - Reading and following application instructions
  - Conducting soil sampling and testing
- Addressing stormwater runoff through farming controls, such as conservation tillage farming, erosion control, or vegetative buffer strips

Resources for agricultural management are provided in Appendix I and include:

- On-Farm Strategies to Protect Water Quality, New England Small Farm Institute
- USDA Tools to Support Source Water Protection, American Water Works Association

4.2.1 Comprehensive Nutrient Management Plans

One of the biggest challenges of agricultural activities in the watershed is the potential for excess nutrients from fertilizers and animal waste in the runoff that eventually drains into the reservoirs. Under the right conditions, the presence of excess nutrients can lead to algal blooms, as the City experienced during the summer of 2020.

Comprehensive Nutrient Management Plans (CNMPs) are conservation plans unique to livestock operations. These plans document practices and strategies adopted by livestock operations to address natural resource concerns related to soil erosion, livestock manure and disposal of organic by-products.

Farms within the watershed should develop a CNMP for their agricultural operations. The Natural Resources Conservation Service (NRCS), an agency within the United States Department of Agriculture (USDA), provides technical guidance and templates for developing a CNMP. Examples of NRCS guidance and a template for a CNMP are included in Appendix J.

The following paragraphs summarize an article from conference proceedings from "Managing Nutrients and Pathogens from Animal Agriculture – A Conference for Nutrient Management Consultants, Extension Educators, and Producer Advisors" held March 28-30, 2000 in Camp Hill Pennsylvania. The article is specific to developing a CNMP for dairy operations, See Appendix J for a copy of the full article.

Some key components of an effective Nutrient Management Plan include: 1) a Farmstead Plan, 2) a Waste Utilization Plan, and 3) accurate record keeping.

Within the Farmstead Plan, there are four primary sections: 1) executive summary, 2) business plan, 3) evaluation of existing conditions, and 4) environmental compliance plan. The executive summary describes the farm setting, soils, animal population, crop acreage, and average production of each commodity. The executive summary should also identify and characterize the watershed and sensitivity concerns within the watershed. The business plan should define the goals and objectives for the farm over the next five years to help the owner formulate a course of action and develop budgets. Any planned expansions should be considered in the business plan. The evaluation of existing environmental conditions should include the farm's ability to address waste management during a significant storm event under its existing operations and identify gaps in the proper handling of waste. The final section incorporates the previous sections to develop recommendations to bring the farm into compliance.

The Waste Utilization Plan measures whether the farm has sufficient land area to accommodate the waste produced, determines if storage needs to be constructed or expanded, and designates the proper time to spread manure based on various risk levels. This is determined based on accounting for the total amount of nutrients to be spread and the characteristics of the land base at the farm. NRCS has animal waste management software available online to help estimate manure production and determine the sizing of waste storage and treatment facilities.

Finally, once the plan is developed, accurate and complete record keeping is necessary to ensure that the farming operations continues to adhere to the nutrient management goals established in the CNMP. The nutrient management plan should include an assessment of the level of recordkeeping that will be necessary to ensure continued conformance to the plan. The more comprehensive and accurate the farm's records, the easier it will be to assess and demonstrate conformance to the plan.

4.2.2 NRCS Resources

The Natural Resources Conservation Service (NRCS) is an agency within USDA that is primarily responsible for land conservation efforts. The NRCS has resources and funding available to help farms adopt voluntary measures to improve their operations while promoting source water protection. These programs provide financial assistance to farmers for voluntary conservation efforts. As a public water supplier, the City of Newburyport is not directly eligible for funding under these programs but could serve as a partner to the farms that are seeking assistance. Many of the NRCS programs include a match component to funding that can be satisfied through a cash match, in-kind services, or a combination. By developing and fostering relationships with the agricultural landowners within the watershed, the City could become their partner and provide support should they decide to seek funding to improve their operations to address source water protection efforts.

Some of the tools for assessing and mitigating for agricultural impacts on water quality are summarized in Appendix I

Table 4-2
Plans

Acronym	Full Name	Application
BMP	Best Management Practice	Stormwater management systems and facilities including structural or biological devices that temporarily store, treat, or convey stormwater runoff to reduce flooding, remove pollutants, recharge groundwater, and provide other amenities. They can also be nonstructural practices that reduce pollutants at their source.
CNMP	Comprehensive Nutrient Management Plan	Nutrient management plans are documents of record of how nutrients will be managed for plant production and to address the environmental concerns related to the offsite movement of nutrients from agricultural fields. This includes developing a farmstead plan identifying the farm uses and locations on the property. A template can be found here: https://nerc.org/documents/manure_management/comprehensive_nutrient_management.pdf
IMP	Integrated Pest Management	Integrated pest management (IPM) is an ecosystem-based strategy to mitigate the risks associated with pest management activities in a sustainable approach to manage pests using a combination of techniques such as chemical tools, biological control, habitat manipulation, and modification of cultural practices and use of resistant varieties.
	Recreation Management Plan	Recreation Management Plans identify what recreational uses are allowed and where, and what recreational uses are prohibited. The plans may also include Best Management Practices for education, control of uses, and enforcement.
SWPPP	Stormwater Pollution Prevention Plan	SWPPPs identify potential sources of storm water pollution at a site and specifies structural and non-structural controls that will be in place to minimize negative impacts caused by storm water discharges associated with site activities. The purpose of these controls is to minimize erosion and run-off of pollutants and sediment. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_042753.pdf
WUP	Waste Utilization Plan	Waste utilization is using agricultural wastes such as manure, wastewater and/or other organic residues. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_022114.pdf

4.2.3 Horse Farms

There are horse farms and residential horse owners within the watershed, primarily within the Town of West Newbury. The City of Newburyport identified locations of horse stabling within the watershed as depicted on Figure 3-3. Improper management of manure can contribute to water pollution. Horses should be fenced off from entering tributaries to the reservoirs, as these waterways flow directly to the reservoirs and contribute to the water quality of the reservoirs. Newburyport should also work with West Newbury to implement a manure management bylaw to provide some oversight for horse owners. An example bylaw from the Town of Easton, MA is provided in Appendix K. Additional resources on horse stable and manure management can be found here: https://extension.psu.edu/horse-stable-manure-management.

4.3 Pesticide/Glyphosate Use

The City of Newburyport has adopted a regulation prohibiting the use of pesticides containing glyphosate on City-owned properties, but not for private properties. As part of its coordination efforts with West Newbury and Newbury, the City should encourage these communities to adopt a similar regulation.

The reason the regulation is for City-owned properties only is because the state preempts the local authorities from issuing more stringent regulations on pesticide use. The Massachusetts Pesticide Control Act places the exclusive authority in regulating the labeling, distribution, sale, storage, transportation, use and application, and disposal of pesticides in the Commonwealth with the Pesticide Board (Chapter 132B, Section 1).

Municipalities can implement pesticide use reduction by 1) adopting municipal policies governing pesticide use on municipal-owned land, 2) implementing the State required school Integrated Pest Management (IPM) plans and prohibiting the use of pesticides for purely aesthetic reasons on all public and private school properties, and 3) educating the public about alternatives to pesticides. Municipalities, under the current Massachusetts law, cannot regulate pesticide use by private homeowners or by landscape professionals on private land.

There is currently a bill in the Massachusetts Legislature (H.910 and its companion bill S.2545) that would modify the language in Chapter 132 Section 1 of the Massachusetts General Laws to allow cities and towns, by a majority vote of the legislative body and approval from the municipality's board of health, to adopt ordinances and by-laws that regulate, restrict or prohibit the use and application or disposal of pesticides within the city or town that are more stringent than the standards and restrictions established by Chapter 132. Similar bills have been introduced in previous legislative sessions but have not been successful. The City should work with their state representatives to support this bill and, if passed, establish restrictions within watershed protection areas as discussed in Section 4.1.

4.4 Land Acquisition Program

Control over harmful activities within the watershed is best achieved when the City of Newburyport has actual land ownership, or other direct control regarding allowable land use activities. Thus, the City's land acquisition program should be geared towards acquiring ownership of, or other rights on, key parcels within the watersheds. Once acquired, these lands can then be managed to establish and maintain optimal cover types (vegetative cover) that provide for the long-term protection of water quality.

Protected open space land within the watershed is generally owned by the City of Newburyport, Town of West Newbury and Essex County Greenbelt Association. Newburyport should continue to work with the Town of West Newbury and Essex Greenbelt to incorporate water supply protection needs into the use requirements for these properties within the watershed.

The land acquisition program is aimed at securing additional control over watershed lands in order to expand watershed protection practices to these lands.

The primary goals of the land acquisition program are summarized as follows:

- Acquire lands adjacent to the reservoirs and tributaries, especially those areas threatened by development
- Limit land uses on the watershed to those that do not threaten water quality

An updated plan for land acquisition has been developed and provided to the Water Department. The focus is on properties adjacent to the reservoirs and their tributaries. While some of these properties are developed, Newburyport should continue to work with landowners for right of first refusal, gift, or purchase for priority lands within the watershed. Newburyport should continue to work with local boards and private land trusts, such as the Essex County Greenbelt Association, to pursue land acquisition. In order to fund acquisitions when properties become available, Newburyport should consider establishing an annual budget line item for purchasing land and development rights for watershed protection purposes.

The City can also seek grant opportunities for land acquisition through:

- the Massachusetts Division of Conservation Services (DCS),
- the Drinking Water Supply Protection Grant Program,
- Massachusetts Land and Water Conservation Fund Grant Program, and
- Local Acquisitions for Natural Diversity (LAND) Grant Program.

West Newbury and Newburyport also have access to local Community Preservation Act (CPA) funding. A combination of these funding sources, including a Drinking Water Supply Protection Grant and CPA funding, was recently used to acquire the Roberts Property, a 38-acre parcel adjacent to the Upper Artichoke Reservoir. This acquisition was a joint venture among the Newburyport, West Newbury and the Essex County Greenbelt Association.

Ranking of Priority Parcels

The priority of properties within the watershed of the Reservoirs was defined by:

- Proximity to the reservoir
- Proximity to a tributary to the reservoir

As there are key privately owned properties adjacent to the reservoirs and their tributaries, these were prioritized. While some of these properties are owner occupied, some have development directly along the edge of the reservoir.

"High" priority parcels have a high potential impact on the reservoir. The focus is on land surrounding Indian Hill Reservoir as this reservoir has several privately owned parcels, a small watershed and increasing nutrient impact to water quality. It is recommended that Newburyport focus on either acquisition of the properties or acquisition of a conservation easement that limits develop (including lawns) along the boundaries of the reservoirs. Indicated by red parcels.

“Moderate" priority parcels have potential impact to a reservoir due to their proximity to the reservoir or a tributary. It is recommended that these parcels establish a 50-foot to 100-foot conservation restriction zone along the waterway. The size of the conservation restriction zone should be implemented in accordance with the size and characteristics of each individual parcel. Indicated by yellow parcels.

"Low" priority parcels have a minimal respective impact to the reservoirs, but still have a potential for reservoir contamination. Indicated by orange parcels.

The City should maintain and update this list and continue efforts to acquire or otherwise protect watershed land as this is one of the best means of protecting the drinking water reservoirs.

4.5 Forestry Management

The main objective of forest management within a watershed is to maintain the high quality water of the surface water sources. The quality of water and the rate at which it is produced is dependent on the type of management the watershed land receives. Managed forests of young, vigorously growing trees provide the best watershed protection. The tree cover acts as a layered filter for purifying the water that passes through it. The tall crowns of the forest overstory add depth to this filter and provide temperature regulation of the surface, ground, and stream waters. The forest understory provides uninterrupted recovery from the overstory losses. The layers of the forest overstory canopy, the forest understory, the vegetated ground cover, and the organic mat of decomposing matter on the forest floor, as well as root systems interspersed within the mineral soil below, all work in concert to produce water of high quality.[2]

The watershed of Artichoke Reservoir system is not very forested, and therefore forestry management has not been a high priority. The City may wish to consider hiring a consulting forester to inventory the forest within the watershed and develop a forestry management plan to determine if any forestry best management practices are warranted. The focus of this effort can be on Parcel R-19, an approximately 35 acre parcel off Turkey Hill Road and the parcels located north of Plummer Spring Road.

In addition to forest management for water supply protection, Newburyport needs to address vegetation management along the embankments of the dams, particularly the Lower Artichoke Dam, to meet Massachusetts Department of Conservation and Recreation Office of Dam Safety requirements.

4.6 Aquatic Conditions Management

Newburyport has been working with limnologists at DK Water Resource Consulting LLC on addressing aquatic vegetation, algal blooms and in-reservoir conditions. The recommendations for addressing in-lake conditions have been identified in the Water

[2] O’Connor, Robert, Thom Kyker-Snowman, Paul Lyons, Bruce Spencer. *Quabbin Watershed: MDC Land Management Plan 1995 - 2004*. June 21, 1995.

Quality Summary and Discussion of 2020 Cyanobacteria Blooms prepared by Don Kretchmer CLM and Ken Wagner PhD CLM in Appendix D. The 2016 Newburyport Reservoir Water Quality Study Report prepared by AECOM also included recommendations for in-lake management. These recommendations are summarized below. As additional data is collected based on the January 2021 Newburyport Reservoirs Water Quality and Cyanobacteria Monitoring Plan prepared by DK Water Resource Consulting LLC in Appendix E, the in-lake recommendations should be reviewed with the limnologist to confirm or modify recommendations based on the additional sampling activities.

Continued aquatic vegetation surveys at all four reservoirs are recommended to monitor the presence and extent of aquatic plants. Continued surveys are necessary to identify if new invasive species (not previously observed) become established in any of the reservoirs and to detect increases in invasive species currently present before they can expand to nuisance concentrations.

Results of the continued surveys should be compared to the results of the 2015 aquatic vegetation survey and vegetation management should be considered if invasive species densities appear to be noticeably increasing.

4.7 Recreational Use Management

A Recreational Management Plan is intended to allow public use of the reservoir areas in a manner that is consistent with and will facilitate watershed protection efforts to ensure a safe, potable water supply. The objectives of the recreational management plan are to provide limited public access and use of the City's watershed resources, assist in identifying potential human activity threats to a supply source, determine whether the watershed can be shielded from those identified threats, and protect the water quality from future human activity threats.

The lands around the reservoirs have been used for passive recreation by the public, including dog walking and horseback riding. Dog and horse waste left on the trails or in proximity to the reservoirs can be carried by stormwater into the reservoirs or leach into groundwater that interfaces with the reservoirs. Under the Massachusetts Drinking Water Regulations (310 CMR 22.20B(4)): "No stabling, hitching, standing, feeding or grazing of livestock or other domestic animals shall be located, constructed, or maintained within 100 feet of the bank of a surface water source or tributary thereto." It is important for dog walkers and horseback riders to be reminded of the importance of rules for picking up waste with signage and potentially dog waste stations, where bags and a disposal bin are provided. Outreach materials are provided in Appendix L.

The goals of a recreational management plan are summarized as follows:

- Create a balance between protection of the watershed and allowance of public access such that the water quality of the surface sources is not jeopardized.
- Maintain the high raw water quality of the surface sources.
- Improve public understanding of the need to protect the water sources.
- Eliminate liability for injuries that may occur during unauthorized activities on watershed property.

- Maintain ultimate control over the watershed areas to ensure a safe, drinking water source.

Section 3.5 summarizes the allowable and prohibited uses within the watershed. The City of Newburyport owns limited property around the edge of the reservoirs, and maintains signage listing restrictions. As additional land is acquired for open space and watershed protection, Newburyport should continue to work with the open space landowners (such as Essex County Greenbelt Association) to incorporate watershed protection revisions. As Newburyport acquires additional property, a formalized recreational management plan can be developed to include additional measures, such as signage and watershed patrols, to further protect the watershed.

4.8 Roadway Management

Protection and repair of the roads around the reservoirs is an important priority. Moulton Street along Indian Hill Reservoir and Turkey Hill Road and Rogers Street along the Upper Artichoke Reservoir have had past problems with excessive erosion. There is limited buffer between the roadway edge and the reservoirs. Roadways can negatively impact the reservoirs by concentrating and accelerating run-off and causing erosion, increasing stormwater pollution, and interrupting subsurface flows.

Future design considerations for these roads should include options to pull the roadway edge away from the reservoir embankment, superelevate or bank the roads away from the reservoirs, install swales, guardrails, and riprap to help address roadway erosion issues and install structural best management practices to pretreat stormwater. Deicing practices should also be assessed, as chlorides can negatively impact the drinking water quality and sand can cause sedimentation and carry other pollutants into the reservoirs. A low or no salt zone should be considered for the roadways that directly abut the reservoirs and their tributaries. Other roadways within the watershed should be monitored for similar erosion and pollution issues.

4.9 Public Education

The development of a public education program for landowners, especially those that abut the reservoirs, will help to address and mitigate impacts within the watershed. The program could focus on effective agricultural BMPs, fertilizer applications, pesticide management, and septic system maintenance for residential landowners.

Outreach to landowners, residents, farms and users of the public lands within the watershed is recommended. The City's goal is to provide information on the watershed, the water quality concerns and the steps that the public can take to better protect the watershed and the reservoirs. Target audiences include:

- Essex County Greenbelt Association and recreational users
- Recreational users of Newburyport's watershed lands
- West Newbury residents and property owners within the watershed
- Newbury residents and property owners within the watershed
- Newburyport residents and property owners within the watershed

Table 4-3 provides a list of communication options for educating the public about watershed issues.

Table 4-3
Communication Methods

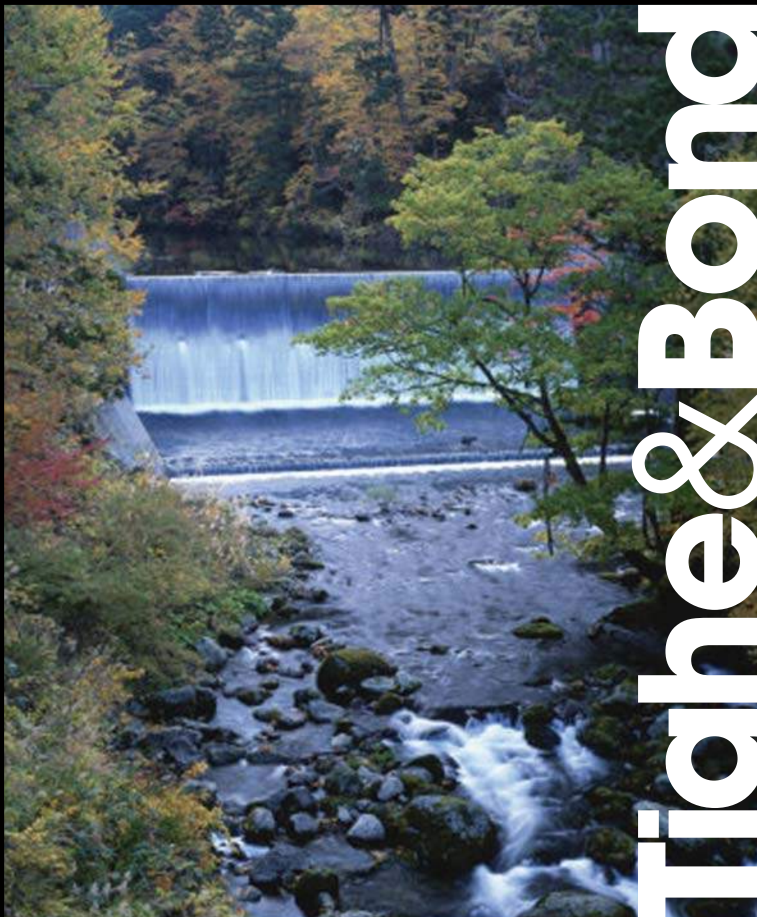
Communication Method	Purpose	Audience
Direct Mail to Property Owners	Notification letters sent to property owners to inform them of water quality concerns and BMPs they can implement.	• Property owners within watershed
Public Outreach Meetings	Public outreach meeting specific to water quality and watershed protection, including a description of the vulnerability of the water supply and actions the public at large can take to protect the reservoir's water quality	• Town and City officials • Public at Large • Property owners within watershed
Webpage	A summary of the water quality resources will be provided on the City of Newburyport website	• Public at Large • Project Neighbors • Members of the Community
Informational Contact Information	Identify a staff person at the Newburyport Water Department to be available to answer questions about water quality.	• Public at Large • Project Neighbors • Members of the Community
Door Hangers	Provides physical door hanger signs with watershed information and contact information.	• Property owners within watershed
Signage at public properties, including City-owned watershed lands and Essex Greenbelt properties	Provide signage on allowed uses, prohibited uses, and reminders to pick up and properly dispose of pet waste	• Recreational users of watershed lands, including dog walkers and horseback riders
Direct contact through mail/ discussions	If issues are identified that directly impact the reservoir water quality, the City of Newburyport will work with the West Newbury and Newbury Town Managers and Health Agents to make contact with the appropriate landowner to address the situation.	• Property owners

4.10 Watershed Protection Committee

As the watershed spans three communities, and encompasses many land uses, we recommend establishing an advisory Watershed Protection Committee that includes representative from Newburyport, West Newbury and Newbury. The committee could provide support to the Newburyport Department of Public Services (DPS) Water Division with review of proposed developments within the watershed, coordinate on opportunities for land acquisition, and assist with outreach to the public.

In addition, Newburyport could consider assigning water supply protection duties to a current staff person or a new staff person to conduct watershed inspections and water quality testing, conduct public outreach including outreach to schools, watershed groups, and local boards. Much of this effort is similar to the duties performed by the Engineering Department's Stormwater Engineer for the NPDES MS4 Permit compliance work.

This staff person could also be responsible for conducting outreach to the watershed property owners, reviewing land management plans (e.g, SWPPPs or CNMPs) and permit applications, pursue grant opportunities, perform watershed inspections, and act as a liaison with West Newbury and Newbury for watershed protection.



SECTION 5

Section 5
Resiliency Recommendations

5.1 Resiliency Concerns

Protection of the watershed will help to ensure a continued safe water supply, but in addition to the need for improved watershed protection, the City of Newburyport's water supply system is at the confluence of multiple climate change issues:

- increased air and thus water temperatures impacting the water quality in shallow reservoirs,
- increased drought potential,
- increased potential of the Merrimack River overtopping the Lower Artichoke Dam and contaminating the Lower Artichoke Reservoir through a storm surge and sea level rise,
- increased frequency and intensities of storm events resulting in anticipated higher pollutant loadings into the reservoirs, and
- increase in 100-year flood levels above the Lower Artichoke Dam's crest.

This section summarizes some of the climate change concerns that the City of Newburyport faces along with options that were investigated as part of this study to address resiliency of Newburyport's critical infrastructure. For more detail on climate change impacts, refer to the City's *Climate Resiliency Plan*, dated October 8, 2020.

By reviewing its critical infrastructure and planning for options to respond to adverse climate change impacts, the City will be prepared to address the multiple aspects of watershed and water supply management including resilience, dam stability, water quality protection, and sustainability.

5.1.1 Sea Level Rise

As a coastal community, rises in sea level will greatly impact Newburyport. Even a small increase in sea level can impact areas farther inland and can cause destructive erosion, flooding, and aquifer and agricultural soil contamination with salt. Rising sea levels can also coincide with more dangerous hurricanes that move more slowly and drop more rain, which may contribute to more powerful storm surges that can cause significant damage.

Sea level rise combined with storm surges will eventually result in the overtopping of the Lower Artichoke Dam by the Merrimack River. The Newburyport Resiliency Committee (NRC) proposed using 6 feet of sea level rise (SLR) in the *Recommendation of Sea Level Rise for Newburyport's Waterfront West Technical Report* dated February 2019. The City of Newburyport asked Tighe & Bond to use this SLR value to identify climate change impacts.

5.1.2 Drought

Drought is a natural phenomenon in which rainfall is lower than average for an extended period of time. Periods of drought can result in inadequate water supply and can lead to public health problems. A drought can exponentially lower reservoir levels because of higher evaporation rates (dry air, especially with wind) and lack of recharge. Droughts also increase water temperature, which contribute to water quality issues and algal blooms.

In Massachusetts, drought conditions during the summer months have become increasingly more common. Drought conditions can affect communities depending on the structure and capacity of existing water systems and the governance of local water usage. The Massachusetts Drought Management Task Force provides and analyzes data to assess the severity of drought conditions and develop appropriate drought responses. The Massachusetts Drought Management Plan, published in September 2019, serves as a guide to Massachusetts communities for drought management planning.

The 2019 Massachusetts Drought Management Plan notes that annual precipitation in Massachusetts has been increasing, however, more precipitation is falling during extreme weather events, in between longer dry periods. Extreme precipitation events do not have the same impact on recharge to groundwater or replenishing of ground or surface water supplies as much of the water runs off instead of replenishing the ground water or contributing to steady streamflows. Recommendations for preparing for impacts from drought include:

- Reassess the safe yield for the reservoir system and include consideration of increased evaporation related to increased temperatures.
- Develop a drought preparedness and response plan and water conservation program.
- Review adequacy and status of intermunicipal agreements and emergency preparedness plans, including the development of emergency connections with neighboring or regional systems.
- Assess participation in the voluntary Massachusetts Water/Wastewater Agency Response Network (MAWARN), which allows public water and wastewater systems to receive rapid mutual aid and assistance from other public systems to restore services damaged by natural or human-caused incidents

Newburyport currently has authority to issue a Water Use Restriction per Section 14-20 of the Code of Ordinances. The City can issue one or more of the following restrictions to protect the water supply:

- *Odd/even day outdoor watering.* Outdoor watering by water users with odd numbered addresses is restricted to odd numbered days. Outdoor watering by users with even numbered addresses is restricted to even numbered days.
- *Outdoor watering ban.* Outdoor watering is prohibited.
- *Outdoor watering hours.* Outdoor watering is permitted during daily periods of low demand, to be specified in the declaration of a state of water supply conservation and public notice thereof.
- *Filling swimming pools.* Filling of swimming pools is prohibited.
- *Automatic sprinkler use.* The use of automatic sprinkler systems is prohibited.

The City should consider reviewing the current Water Use Restriction Ordinance and updating it to be in conformance with updated model language from MassDEP. Updates to the Ordinance should consider the following:

- Providing a definition of Non-essential Outdoor Water Use that includes examples and exceptions.
- Including within the revised ordinance a designee of the Board of Water and Sewer Commissioners, such as the DPS Director of Water Treatment Superintendent, who can declare a State of Water Supply Conservation or State of Water Supply Emergency. This avoids any delay in imposing restrictions until the next scheduled board meeting.
- Prohibiting outdoor watering at a minimum, between 9AM and 5PM. This is consistent with good irrigation practices which seek to avoid irrigation during periods of high evapotranspiration.
- Removing "odd/even day watering" and replacing it with a limitation on the allowed number of days per week of watering. No more than two days per week is recommended, with the actual number of days and particular hours (outside the 9 am to 5 pm window) to be determined by the Board of Water Commissioners or its designee.
- Adding an option that would require private well users to abide by restrictions imposed by the community or water district.
- Adding a definition of a State of Drought and an option to institute additional restrictions during a declared drought.
- The addition of an optional section at the end of the bylaw that regulates the use of in-ground lawn and garden sprinkler systems.

5.1.3 Temperature Increases

Increases in temperature due to climate change contribute to rising sea levels (melting ice caps and thermal expansion of the oceans), increased water reservoir temperatures, and increased and worsening of drought conditions. Concerns associated with rising temperatures can include limited water availability through increased evaporation and increases water demand (including demand for irrigation) and increases in extreme precipitation events that are followed by extended dry periods.

Increased temperature within the reservoir systems will increase the likelihood of algal blooms as toxic blue-green algae prefer warmer water, warmer water is easier for small organisms to move through and allows algae to float to the surface faster, and algal blooms absorb sunlight, making water even warmer and promoting more blooms, thus creating a problematic feedback loop.

In addition, increased air temperatures will increase the temperature of the pavement and ground surface in the watershed, which thereby increases the temperature of stormwater runoff traversing these surfaces. The hotter stormwater runoff will result in warmer reservoir temperatures which enhance the environment for algal growth.

Options for keeping the reservoir water cooler could include:

- Dredging to increase water depth. Dredging is also a useful option for removal of nutrient and other pollutants that have settled on the reservoir floor; however, dredging is not anticipated to have a significant impact on the reservoir temperature as the amount of material required to be removed to achieve a reservoir depth to make a difference in the temperature would not be technically or economically feasible.
- Increasing the height of the reservoirs by increasing the height of the Lower Artichoke Dam. This option would require the City to acquire additional land for the construction of the dam and for the taking of property for reservoir use (accounting for the land proposed to be covered by water with the increased reservoir height). This option would require significant coordination with adjacent landowners and significant environmental and dam-related permitting. Regulators have been reluctant to permit increases in dam heights for storage increases.
- Adding aerators to the reservoirs can increase the movement of the water in the reservoirs and decrease the temperature. Added aeration may also result in increases evaporation.
- Installation of floating solar panels can help shade the reservoir and provide a potential revenue source.
- Floating wetlands could provide some shading of the reservoir and uptake nutrients to help address algal blooms.

These options would have to be further assessed to determine which are feasible and offer the highest value for the cost.

5.2 Reservoir Protection Options

The City of Newburyport's Indian Hill, Upper Artichoke and Lower Artichoke reservoirs are created by three dams.

- Lower Artichoke Reservoir Dam has a maximum structural height of approximately 10 feet and a maximum storage capacity of approximately 415 acre-feet. The earthen embankment dam extends approximately 4,425 feet in length. The primary spillway consists of an approximately 80-foot long reinforced concrete ogee-shaped weir. The spillway has reinforced concrete training walls and discharges directly into a ponded area downstream of the dam before flowing into the Artichoke River. In accordance with Department of Conservation and Recreation (DCR) classification procedures, under Commonwealth of Massachusetts 302 CMR 10.00 Dam Safety, revised February 10, 2017, Lower Artichoke Reservoir Dam is an Intermediate size structure based on storage.

- Upper Artichoke Reservoir Dam is a run-of-the-river style dam extending 225 feet in length and has a maximum structural height of approximately 9 feet and a maximum storage capacity of approximately 85 acre-feet. Therefore, in accordance with DCR classification procedures, Upper Artichoke Reservoir Dam is an Intermediate size structure based on storage.

- Indian Hill Reservoir Dam is the uppermost dam of Newburyport's public water supply system. The dam is an earthen embankment dam with a primary spillway and outlet works. A dike is located approximately 1,400 feet from the right abutment of the dam referred to as South Dike. A second dike is located approximately 2,500 feet from the left abutment of the dam referred to as North Dike. Indian Hill Reservoir Dam has a maximum structural height of approximately 30 feet and a maximum storage capacity of approximately 2,955 acre-feet. Therefore, Indian Hill Reservoir Dam is a Large size structure based on storage.

As failure of each dam at maximum pool will likely cause minimal property damage to others and loss of life is not expected, all three dams are currently classified in accordance with DCR classification procedures, under the Commonwealth of Massachusetts Regulations 302 CMR 10.00 Dam Safety, as revised February 10, 2017, as Low (Class III) hazard dams.

As low hazard dams, the requirements for inspections and maintenance are less stringent than for higher hazard dams. However, should a dam breach occur, it would have significant repercussions to the Newburyport Public Water Supply; therefore, a higher hazard classification should be considered since the dams support water supply reservoirs.

This section details the current condition and needed maintenance of the dams; temporary measures for protection of the Lower Artichoke Dam spillway from a potential backwater breach from the Merrimack River; and options for improving the dam system to make the reservoir system more resilient. The recommendations regarding the dams are provided in the sections below.

5.2.1 Dam Maintenance Recommendations

In order to assess the current condition of the dams, Tighe & Bond inspected the Lower Artichoke Reservoir Dam, Upper Artichoke Reservoir Dam, and Indian Hill Reservoir Dam on July 27, 2020. This information was used for evaluating the present condition of the dams and appurtenant structures to assist in both prioritizing dam repair needs and planning/conducting maintenance and operation. The recommendations presented in the Inspection/Evaluation report dated July 27, 2020, provided as Appendix M, are from a dam safety perspective and do not consider other factors, particularly possible backwater events from the Merrimack River. Prior to conducting repairs recommended in this report, the City should make a decision regarding the resiliency improvements. If the City decides to move forward with the resiliency improvements, certain recommended dam safety improvements for the Lower Artichoke Reservoir Dam can be postponed and/or incorporated into the resiliency project.

The following is a summary of the recommended maintenance and repairs for the existing dams. For details regarding the condition of the dams, maintenance recommendations and the maintenance related costs, see the 2020 Inspection / Evaluation Report in Appendix M.

Recurrent Maintenance Recommendations – All Dams

The following recommended activities should be performed on a regular, or yearly, basis and recorded:

1. Regularly monitor the embankment for animal burrows, localized depressions, bare spots, and any other type of unusual activity.

2. Regularly mow (minimum of three times per year) the embankment, abutments, and within 20 feet of the dam to control tree and brush growth which inhibits proper visual observations of the dam.

Recommendations, Maintenance, and Minor Repairs – All Dams

The following repairs and maintenance items are recommended to improve the overall condition of the dams:

1. Remove trees and brush on the embankment, abutments, and within 20 feet of the dam in accordance with the Massachusetts Office of Dam Safety's Policy on Trees on Dams. It is recommended that stumps and roots be removed in their entirety, as roots can shrink as they decay, which could cause preferential seepage paths. Backfill all voids with appropriate material, which would vary based on the location on the dam.

Recommendations, Maintenance, and Minor Repairs – Lower Artichoke Reservoir Dam

1. Fill the lower elevation sections of the embankments to maintain a constant elevation along the entire length of the structure.
2. Armor the upstream slope of the embankments with additional riprap to limit erosion due to fluctuating water levels and wave action.

Recommendations, Maintenance, and Minor Repairs and Remedial Modification Recommendations– Upper Artichoke Reservoir Dam

1. Monitor efflorescence and repair cracks and spalling of concrete along spillway, gate structures and training walls.
2. Install railing along the training walls and abutment to limit fall hazards.

Recommendations, Maintenance, and Minor Repairs – Indian Hill Reservoir Dam

1. Supplement existing armoring along upstream slope with additional riprap stone. Armoring should extend to spillway design flood water surface elevation.
2. Level the earthen dam crest and apply a gravel layer to areas of exposed soil.
3. Monitor and repair concrete cracking along gatehouse structure.

5.2.2 Lower Artichoke Dam – Temporary Protection Options

The Merrimack River FEMA base flood (i.e., 100-year frequency flood) elevation is approximately 3 feet higher than the concrete spillway of Lower Artichoke Reservoir Dam. Under certain conditions, brackish and polluted water from the Merrimack River will flow into Lower Artichoke Reservoir if the regulatory base flood occurred at the Merrimack River. If the Lower Artichoke Reservoir Dam or spillway were overtopped by the Merrimack River, it could pose a risk to the drinking water supply, particularly if a breach or overtopping were to occur when the Merrimack River is at flood stage. As seawater is denser than freshwater, such an inflow would be expected to sink to the bottom of the reservoir and eventually be flushed back downstream over the spillway.

For the purposes of this analysis, a breach is considered to be a backwater or tailwater breach, occurring when water from the Merrimack River extends up the Artichoke River due to a storm surge and sea level rise. Typically, a breach is defined as a dam failure where the impounded water is released downstream.

With sea level rise and more intensive storms anticipated, the potential for a backwater breach of the Lower Artichoke Dam is rising. Influx of water from the Merrimack River into the Lower Artichoke Reservoir will result in additional contaminants and saltwater entering the reservoir, near the only intake for all three of the City's main reservoirs. The WTP is not designed to treat the water from Merrimack River; therefore, a backwater event could take 80% of the City's water supply off-line.

In order to determine events when a backwater breach may occur, Tighe & Bond evaluated a backwater breach of Lower Artichoke Dam using the 2D HEC-RAS hydraulic model. The analysis incorporated Sea Level Rise (SLR) of FEMA + 6 feet, corresponding to elevation 18.2 feet. The results of this analysis, titled Artichoke River - Hydrologic & Hydraulic Analysis Technical Memorandum, dated December 9, 2020, is attached in Appendix N. Portions related to the backwater breach assessment from this memorandum are incorporated below.

The tidal conditions determined for the Merrimack River were based on the FEMA Base Flood Elevation (BFE) listed in the FIS Report for Essex County, Massachusetts and the anticipated sea level rise (SLR) based on the *Recommendation of Sea Level Rise for Newburyport's Waterfront West Technical Report*. These values were used as inputs to the 2D HEC-RAS model as the downstream boundary condition to evaluate the hydraulics at Lower Artichoke Reservoir Dam.

Flooding due to the Merrimack River BFE is anticipated to be from upland flooding from the Merrimack River watershed (i.e. "Merrimack River water"), whereas flooding due to tidal influence from the Merrimack River with SLR (i.e. from the MHHW+SLR) is anticipated to be brackish, including potential coastal storm events occurring at the Merrimack River. Flooding from the Merrimack River BFE+SLR scenario is anticipated to be "Merrimack River water" during the BFE peak, however, would likely be a mix of "Merrimack River water" and brackish water after the BFE peak has passed. Flows from the Artichoke River are assumed to be baseflow during these scenarios with starting elevation levels at approximately the spillway elevation of 8.75 feet NAVD88.

Table 5-1 and Table 5-2 show the peak water surface elevation and freeboard to top of dam computed at Lower Artichoke Reservoir Dam during various storm events in the Artichoke River watershed under MHHW with SLR, and for the FEMA BFE with and without SLR. The low point in the dam crest is at 10.8 feet NAVD88, and the typical dam crest elevation exceeds 12 feet NAVD88. The spillway elevation is at 8.75 feet NAVD88 and is approximately 2.05 feet below the lowest point in the dam crest and approximately 3.25 feet below the typical dam crest.

Lower Artichoke Reservoir Dam is anticipated to overtop at the dam crest due to backwater from the Merrimack River MHHW with SLR during the 10-, 25-, 50-, 100-, and 500-year storm events in the Artichoke River, while the right embankment overtops during all storm events with MHHW+SLR. It is also anticipated that when the Merrimack River is at the FEMA BFE with and without SLR, Lower Artichoke Reservoir Dam will overtop at the right embankment by a maximum of 8.8 feet and 2.8 feet, respectively. Similarly, Upper Artichoke Reservoir Dam located further upstream, is anticipated to overtop by 3.3 feet when the Merrimack River is at the FEMA BFE + SLR, and by 0.6 feet under MHHW+SLR conditions during Artichoke River baseflow.

During the Lower Artichoke Reservoir Dam 100-year storm event under existing conditions, the spillway is anticipated to overtop by 1.1 feet due to upland flooding from the Artichoke River. However, the estimated 6 feet of SLR results in potential impacts to drinking water quality due to brackish water entering the reservoir from backwater from the Merrimack River (Table 5-3). Lower Artichoke Reservoir is anticipated to receive approximately 21.17 MG (32.9% of normal pool volume) of brackish water from the Merrimack River during the 100-year storm event under SLR conditions.

TABLE 5-1
Summary of Peak Water Surface Elevation at Lower Artichoke Reservoir Dam during MHHW+SLR Flooding from Merrimack River

Upland Flooding Condition	Tailwater Flooding Condition	Peak Water Surface Elevation (feet, NAVD88)	Freeboard to Low Point in Dam Crest: 10.8 ft NAVD88 (feet)	Freeboard to Typical Dam Crest: 12 ft NAVD88 (feet)
2-year	MHHW[1] + SLR[2]	10.6	0.2	1.4
5-year	MHHW[1] + SLR[2]	10.7	0.1	1.3
10-year	MHHW[1] + SLR[2]	10.9	-0.1	1.1
25-year	MHHW[1] + SLR[2]	11.2	-0.4	0.8
50-year	MHHW[1] + SLR[2]	11.5	-0.7	0.5
100-year	MHHW[1] + SLR[2]	11.9	-1.1	0.1
500-year	MHHW[1] + SLR[2]	12.9	-2.1	-0.9
Baseflow	FEMA BFE[3]	12.2	-1.4	-0.2
Baseflow	FEMA BFE[3] + SLR[2]	18.2	-7.4	-6.2

[1]Mean higher high water
[2]Sea level rise
[3]Federal Emergency Management Agency Base Flood Elevation

TABLE 5-2
Summary of Peak Water Surface Elevation at Upper Artichoke Reservoir Dam during MHHW+SLR Flooding from Merrimack River

Upland Flooding Condition	Tailwater Flooding Condition	Peak Backflow (cfs)	Peak Water Surface Elevation (feet, NAVD88)	Freeboard to Top of Dam: 14.9 ft NAVD88 (feet)
2-year	MHHW[1] + SLR[2]	-	13.0	2.0
5-year	MHHW[1] + SLR[2]	-	13.5	1.4
10-year	MHHW[1] + SLR[2]	-	13.8	1.2
25-year	MHHW[1] + SLR[2]	-	14.1	0.8
50-year	MHHW[1] + SLR[2]	-	14.4	0.5
100-year	MHHW[1] + SLR[2]	-	14.7	0.2
500-year	MHHW[1] + SLR[2]	-	15.5	-0.6
Baseflow	FEMA BFE[3]	-	12.4	2.5
Baseflow	FEMA BFE[3] + SLR[2]	-1,371[4]	18.2	-3.3

[1]Mean higher high water
[2]Sea level rise
[3]Federal Emergency Management Agency Base Flood Elevation
[4]Backflow volume under this scenario is 274 million gallons over 72 hours (of 2D HEC-RAS hydraulic model simulation time) which is approximately 143% of normal pool volume; this is the only scenario in which Upper Artichoke Reservoir Dam overtops due to backwater.

TABLE 5-3
Lower Artichoke Reservoir Dam - Summary of Backwater Inflow during Flooding from Merrimack River

Upland Flooding Condition	Tailwater Flooding Condition	Peak Backflow (cfs)	Backflow Volume Over 72[4] Hours (MG)	Percent of Normal Pool Volume
2-year	MHHW[1] + SLR[2]	-471	21.2	33.0%
5-year	MHHW[1] + SLR[2]	-471	21.2	33.0%
10-year	MHHW[1] + SLR[2]	-471	21.2	33.0%
25-year	MHHW[1] + SLR[2]	-471	21.2	33.0%
50-year	MHHW[1] + SLR[2]	-471	21.2	33.0%
100-year	MHHW[1] + SLR[2]	-471	21.2	32.9%
500-year	MHHW[1] + SLR[2]	-471	21.1	32.9%
Baseflow	FEMA BFE[3]	-515	55.9	86.9%
Baseflow	FEMA BFE[3] + SLR[2]	-3,812	720.1	>100%

[1]Mean higher high water
[2]Sea level rise
[3]Federal Emergency Management Agency Base Flood Elevation
[4]72 hours of 2D HEC-RAS hydraulic model simulation time

The key points regarding the potential for a backwater breach from the Merrimack into the Lower Artichoke Reservoir are summarized below:

- Backwater from the Merrimack River is expected to exceed the Lower Artichoke Reservoir Dam spillway elevation, and potentially impact the water supply, for storm events slightly larger than the 10% annual exceedance flood (AEP), also known as the 10-year frequency storm event.
- The peak water surface elevation anticipated during the 50-year frequency storm event, which is the dam's regulatory Spillway Design Flood (SDF) per the Massachusetts dam safety regulations is 11.5 feet during Mean Higher High Water (MHHW) Merrimack River tidal conditions with and without accounting for Sea Level Rise. This flood depth overtops the low point in the dam embankment by 0.7 feet. (Note that the regulatory SDF for a new Low Hazard Potential dam would be the 100-year frequency storm.)
- The peak water surface elevation anticipated during the Artichoke River 50-year SDF with Merrimack River MHHW plus SLR tidal conditions is anticipated to cause backwater to enter the reservoir at the low points along the embankment, resulting in an estimated 21 MG of Merrimack River water entering the reservoir over 72 hours (corresponding with approximately 33 percent of the normal pool reservoir volume).
- The volumes presented are estimated maximum values, assuming that there is no water flowing from over the spillway from the reservoir. During a storm event, there will likely be water flowing over the spillway, resulting in a hydraulic head against the water rising up from the Merrimack River. It is unclear how the two water sources will mix.
- If a 100-year flood occurred at the Merrimack River, an estimated 56 MG of Merrimack River water would enter Lower Artichoke Reservoir over 72 hours (corresponding with approximately 87 percent of the normal pool reservoir volume). If a base flood incorporating sea level rise occurred at the Merrimack River, an estimated 720 MG of Merrimack River water would enter Lower Artichoke

Reservoir over 72 hours (corresponding with approximately 1,120 percent of the normal pool reservoir volume).

It is important to protect the Lower Artichoke Reservoir: its spillway is 3 feet below the current 100 year flood level; the dam embankment height varies and has low spots that are also below the 100-year flood level and susceptible to a backwater breach; and the spillway is susceptible to a backwater breach from the Merrimack River, which would result in contamination of the reservoir. Therefore, options for modifying the current dam were assessed, and included the following:

- Reconfiguration of the Lower Artichoke Dam to minimize the overall length and installation of adjustable spillway crest gates, inflatable dams, or other flood control devices to maintain block backwater during major storm events but would be lowered under non-storm events to maintain the current normal pool elevation. Shorter term methods to protect the Lower Artichoke Reservoir spillway from overtopping during a backwater event will also be evaluated, such as large sandbags (Super Sack) or a water filled dam (AquaDam).
- Permanently raising the Lower Artichoke Dam and spillway to address FEMA flood elevations and SLR

In addition, an option to install a tide gate structure below the Lower Artichoke Dam was considered. This option would allow normal stream outflows but resist Merrimack River backwater during storm events. The tide gate was envisioned to be installed downstream of the existing reservoir dam at the Route 113 bridge. This option was not pursued further due to hurdles associated the impact to the Route 113 bridge, wetland resource areas and MassDOT permitting and costs.

5.2.3 Lower Artichoke Dam Modifications

The current Lower Artichoke Dam is a 4,425 linear foot earthen embankment dam. The earthen embankments extend along both sides of the reservoir, reaching almost to the Upper Reservoir Dam. The dam embankment crest is generally at elevation 12 feet, which is the 100-year FEMA flood plain elevation, but varies gradually along both embankments on either side of the spillway.

The profile of the embankments slope up and down with a maximum difference of elevation of approximately 2 feet with one major point of erosion on the west embankment which is at approximate elevation 10.8.

The following recommended modifications to the dam would alter the current configuration or design of the dam, and should be done regardless if resiliency improvements are made:

1. Remove trees and brush from the earthen embankments in accordance with the Massachusetts Office of Dam Safety's Policy on Trees on Dams
2. Regrade the upstream and downstream side-slopes of the embankments to a maximum 2:1 slope and armor with stone riprap.
3. Re-align the embankment to tie it into surrounding high terrain located closer to the spillway. Strategically integrating the embankments into higher terrain closer to the spillway could significantly reduce the length of embankments, reduce construction costs, minimize areas needing repair and future maintenance, and

minimize future operation and maintenance costs. *This recommendation does not include raising the height of the embankment.* It is anticipated that if resiliency improvements are performed at the dam, including increasing the height of the embankment, they would include tying the embankments into higher terrain.

Costs for these recommendations are provided below.

Table 5.4
Lower Artichoke Dam Maintenance and Modifications to Maintain Current Functionality – Probable costs

	Recommendation	Probable Cost[1]
Short Range Tasks		
1	Remove trees and brush on the embankment, abutments, and within 20 feet of the dam	\$100,000[2]
2	Fill the lower sections of the embankments to maintain a constant elevation along the entire length of the embankment.	\$20,000
Long Range Tasks[3]		
1	Regrade the upstream and downstream slopes of the embankments to a maximum 2:1 slope and armor with stone riprap.	\$200,000
2	Modify the existing embankments by constructing additional sections that would the tie the existing embankments into surrounding terrain located closer to the spillway.	\$650,000
	Total	**\$970,000** **SAY \$1,000,000**

[1] The probable costs shown assume that each task is completed individually. Significant savings on engineering, permitting, and contractor mobilization can likely be obtained by combining multiple tasks.
[2] The cost estimate was determined for approximately 800 feet of embankment on either side of the spillway as it is assumed that the embankments will be modified to reduce their overall length.
[3] The long range tasks are recommended to improve the dam condition as defined by DCR's current rating guidelines and do not include additional measures to prevent backwater from the Merrimack River from impacting the water supply by raising the dam embankment. Recommendations by Tighe & Bond to raise the embankment of Lower Artichoke Reservoir Dam (described below) incorporate the long range tasks listed in this table.

5.2.4 Short Term Spillway Protection Options at Lower Artichoke

Tighe & Bond assessed short-term options to address the concern of back flow over the Lower Artichoke spillway from the Merrimack River. Short term protection is expected to prevent just the spillway from overtopping so the protective measures would be to an elevation of 12 feet. An option to partially block the spillway permanently was considered. Partially blocking the spillway would minimize the amount of additional installation in the event of a storm. Partial blockage of the spillway would constrain the ability of the spillway to pass traditional downstream flows during storm events and that could potentially cause upstream flooding or failure of the dam, therefore, options to permanently block a portion of the spillway were dismissed.

The recommended option includes the construction of a stone foundation along the upstream side of the Lower Artichoke spillway that would allow for the temporary installation of Super Sacks (i.e., large, 1 cy sand bags). Alternatively, an AquaDam® system could be installed immediately upstream of the spillway to block backwater surges from the river. The proposed measures are considered temporary in nature until a permanent solution has been designed and permitted. Prior to forecasted storm events, the super sacks or AquaDam® will be deployed to temporarily increase the spillway elevation to protect the Lower Artichoke Reservoir from storm surges. Additionally, traditional sandbags will be added to a low point portion of the dam embankment to raise the elevation to the FEMA 100-year floodplain elevation.

The Super Sack option requires the construction of an approximately 10-foot wide by 80-foot long foundation within the Lower Artichoke Reservoir. The foundation would consist of the placement of riprap adjacent to the Lower Artichoke spillway, within the concrete wingwall area. In advance of forecasted storms, the City will deploy the Super Sacks atop the stone foundation to temporarily increase the spillway elevation and protect the Lower Artichoke Reservoir from potential storm surges. The spillway will be accessed from the existing driveway to the Lower Artichoke Pumping Station off Route 113. Alternatively, an AquaDam® could be installed upstream the spillway and be founded on the reservoir bottom and the earthen embankments on either side of the spillway. The top of the AquaDam® would be at least to elevation 12 feet once filled. The City is considering construction of a ramp to the east of the spillway to provide access for the heavy equipment necessary to deploy an AquaDam® or Super Sack option. Clearing and repair the western crest and embankment would help facilitate access for heavy equipment to the west of the spillway.

5.2.5 Dam and Spillway Resiliency Options

Tighe & Bond also assessed longer term options for modifying the Upper and Lower Artichoke Reservoir dams to address sea level rise. Per coordination with the City, the SLR used was FEMA + 6 feet for the spillway (el. 18.2 feet) and FEMA + 8 (el. 20.2 feet) for the top of the embankment to provide two feet of embankment freeboard above the water surface elevation to limit potential embankment overtopping that could lead to dam failure. Information on raising the Upper and Lower Artichoke Reservoir Dams is provided below. Note: The City can choose to raise one dam or the other. It is not recommended to raise both dams as raising Lower Artichoke Dam also protects Upper Artichoke Reservoir.

5.2.5.1 Lower Artichoke Reservoir

For the Lower Artichoke Reservoir Dam, the proposed cross-section includes a 10-foot wide crest, embankment with a 2.5:1 slope, rip-rap armoring on both sides and a crest gate at the spillway. The dam would tie into high ground on either side of spillway, to minimize the length of dam. The following design elevations were used:

- 100-year BFE = 12.2 feet
- Proposed Max Spillway Elevation (crest gate “in up position”) = 18.2 feet (FEMA +6’)

- Proposed Top of Dam 20.2 feet

Two options were assessed for the raising of the Lower Artichoke Dam. The options relate to the West Newbury public water supply wellfield. Currently their wellfield is separated from the Lower Artichoke Reservoir by the existing earthen embankment that is part of the dam. Therefore, if backwater from the Merrimack River were to reach this area through the Artichoke River, the wellfield is not protected by the Lower Artichoke Dam.

Option 1 would extend the western boundary of the dam to the north of the West Newbury wellfield. This option will separate the wellfield from backwater flooding from the Merrimack and Artichoke Rivers, but it does not protect the wellfield from possible flooding over the existing embankment from the reservoir. Option 2 maintains an embankment between the wellfield and the reservoir as noted below:

1. Option 1: Increase the height of and extend the dam embankment approximately 500 feet to the east and approximately 800 feet to the west to tie into higher ground in line with the existing spillway. On the west side, the new dam will connect to the driveway into the West Newbury wellfield at a point between the wellfield and Route 113. This is the minimum length for the dam embankment and would minimize overall construction costs. A crest gate would be proposed at the existing spillway. However, if the reservoir rises due to the closed crest gate, the adjacent West Newbury's public water supply wellfield could be flooded by reservoir water overtopping the embankment during certain flooding events.

2. Option 2: Increase the height of and extend the dam embankment approximately 500 feet to the east to tie and approximately 800 feet to the west to tie into higher ground in line with the existing spillway. To the west increase the height of and extend the dam embankment approximately 1,400 feet, ending south of the West Newbury's wellfield. This option is designed to also protect the West Newbury wells from potential flooding from the reservoir and from backwater from the Merrimack or Artichoke Rivers.

The recommend reconfiguration of the dam addresses dam safety, increases the stability of dam, and improves the maintenance of the dam with the addition of a 10 foot wide crest, which is wide enough for a maintenance vehicle to traverse the crest. The crest gate would increase operation and maintenance requirements for this dam.

Raising the dam to elevation 20.2 feet would require extending the dam onto adjacent property, so additional property or easements would need to be acquired.

5.2.5.2 Upper Artichoke Reservoir

For the Upper Artichoke Reservoir Dam, the proposed cross-section includes a 10-foot wide crest, embankment with a 2.5:1 slope, rip-rap armoring on both sides and a crest gate at the spillway. The following elevations were used:

- 100-year BFE = 12.8 feet

- Proposed Spillway Max Elevation (proposed crest gate "closed") = 18.8 feet (FEMA + 6')

- Proposed Top of Dam = 20.8 feet

The Upper Artichoke Dam has an 80-foot crest gate and a shorter embankment than the Lower Artichoke Reservoir Dam. Increasing the height of the Upper Artichoke Reservoir would be less expensive than addressing the Lower Artichoke Dam, but would result in "sacrificing" the Lower Artichoke Reservoir during a surge from the Merrimack River.

5.2.5.3 Summary of Reservoir Improvement Options

Concepts for raising the Lower and Upper Artichoke dams and concept level OPCCs are provided in Appendix O. The OPCCs are summarized in Table 5.5. The costs below do not include the costs of land acquisition that would increase the costs associated with the Lower Artichoke Dam alternatives.

TABLE 5-5
Dam and Spillway Resiliency Options - Opinion of Probable Construction Cost

Alternative	OPCC
Alternative 1, Option 1– Lower Artichoke Dam	$6,900,000
Alternative 1, Option 2 – Lower Artichoke Dam – extended embankment	$8,000,000
Alternative 2 – Upper Artichoke Dam	$4,400,000

5.2.6 Conclusions and Recommendations

The Lower Artichoke Reservoir Dam is susceptible to backflow from the Merrimack River, and as the only existing intake for the three surface water reservoirs is within the Lower Artichoke Reservoir, a backflow event could compromise the use of 80% of the City's water supply. Performing dam maintenance and preparing for emergency protection situation are strongly recommended. Minimizing the length of the Lower Artichoke Reservoir Dam embankment is also recommended, whether or not the embankment height is increased.

While more costly, it is recommended the Lower Artichoke Dam be raised over the Upper Artichoke as major repairs are needed at Lower Artichoke Dam regardless if it is raised and improvements would protect both the Lower and Upper Artichoke Reservoirs. It should be noted that these options only increase the embankment and add a crest gate; they are not proposed to increase the normal reservoir elevation. While the Upper Artichoke Reservoir Dam improvements are less expensive and impact less wetland resource areas, these improvements do not protect the Lower Artichoke Reservoir or the existing raw water intake. The Lower Reservoir Dam improvements would protect the existing intake and the Upper Reservoir as well.

Raising the Lower Artichoke Reservoir water level was not assessed. There are significant regulatory hurdles to increasing the water level of the reservoir. Some of the benefits of increasing the water levels include:

- Increased water storage volumes
- Improved water quality with a deeper water column
- Protection from a backwater event without a mechanical or deployable measure

As there are significant threats to the City's reservoirs, which supply 80% of their public water, and the City has limited opportunities for other water supply sources, an argument could be made for the need to raise the water levels of the Lower Artichoke Dam. Additional studies would be needed, including but not limited to identification of resource impacts, revisions to flood studies and Flood Insurance Rate Map (FIRM), identification of properties that may be impacted, the necessity for land acquisition, and the impact on West Newbury's wells. Before significant effort is spent on these activities, it is recommended to hold an initial discussion with regulators to determine the feasibility of this option.

5.3 Transmission Line Options

A raw water transmission main feasibility alternatives analysis was performed for evaluating pipeline alternatives to allow direct access to the Upper Artichoke and Indian Hill Reservoirs in the event of water quality or flooding concerns that would prohibit utilizing the existing intake in the Lower Artichoke Reservoir. As there is currently one intake for all three reservoirs, at the lowest point in the system, if this intake were compromised the City would lose the use of Indian Hill and Upper and Lower Artichoke Reservoirs, which together constitute 80% of the City's water supply. This secondary raw water transmission main would allow the City to use the Indian Hill Reservoir or the Upper Artichoke Reservoir, without having to use the intake at the Lower Artichoke Reservoir. The feasibility analysis included:

- A review of seven alternative routes from the Upper Artichoke and Indian Hill Reservoir to the existing Artichoke Reservoir raw water pump station and transmission main.
- An analysis of the water main profile for each alternative route to evaluate the need for a pump station at the Indian Hill Reservoir.
- Conceptual opinion of probable construction costs for each alternative

Appendix P contains a figure showing each alternative route considered during the alternatives analysis and detailed opinion of probable construction costs for each alternative.

5.3.1 Raw Water Transmission Main Route Alternatives

Seven alternative routes were analyzed that include routes along existing roadways, cross country routes, and existing paths between the Indian Hill Reservoir and the existing Raw Water Pump Station. Details of each alternative are below. Figures 5-1 to 5-4 illustrate potential access to each Reservoir for each alternative. Appendix P includes a figure of the proposed alternative routes. Several factors were considered for the alignment selection and feasibility analysis for the alternatives. These factors included:

- Temporary and permanent easements
- Environmental and wetland resource area permitting
- Raw water pump station
- Opportunity for manual mixing of the three reservoirs
- Intake construction
- Crossing Upper Artichoke

- Access to Upper Artichoke
- Route 113 Bridge crossing

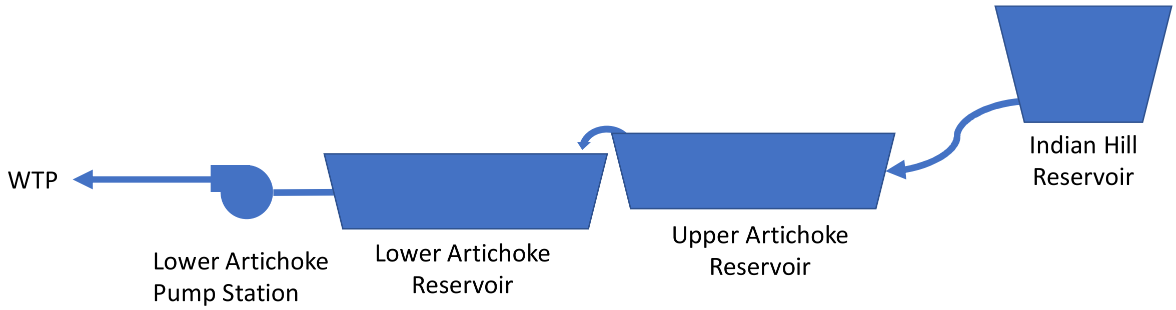


Figure 5-1 Existing Reservoir Water Flow

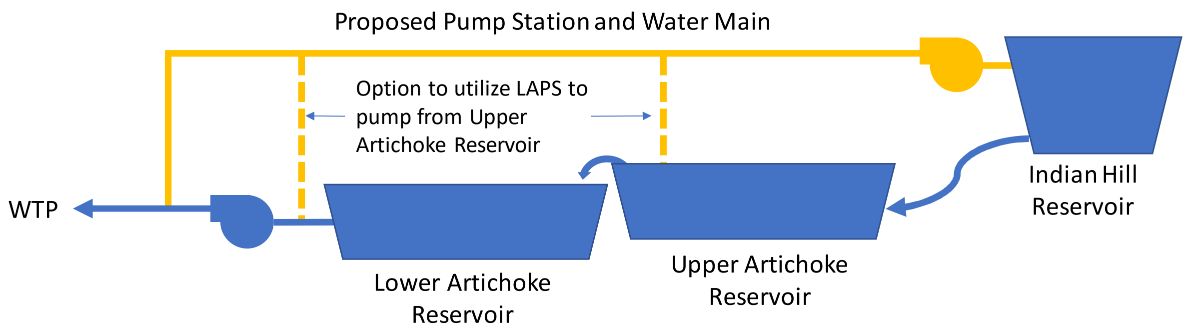


Figure 5-2 Proposed Raw Water Pipeline Alternatives 1, 2, 3, & 6

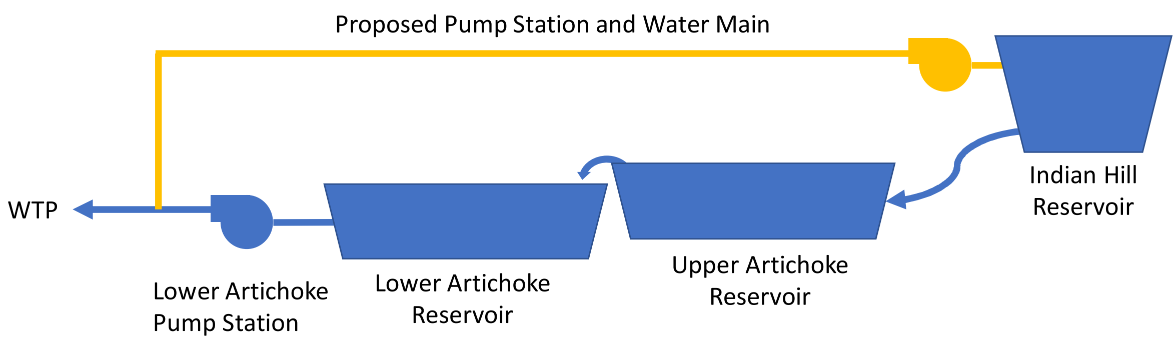


Figure 5-3 Proposed Raw Water Pipeline Alternatives 4 & 5

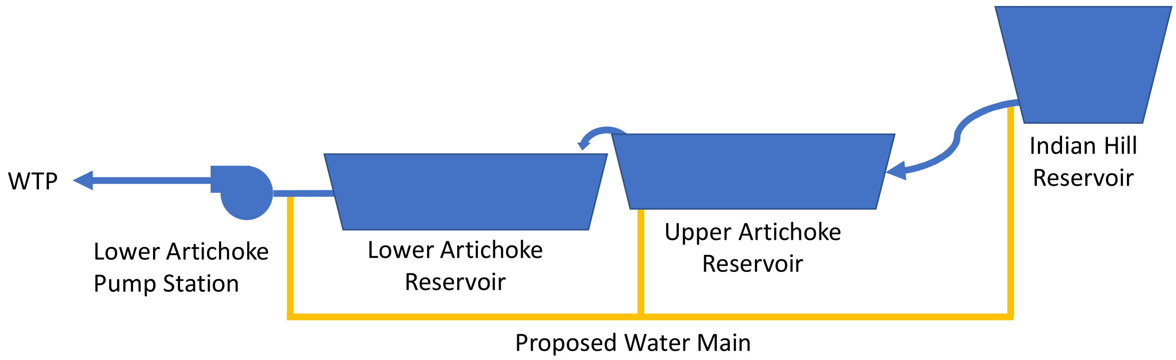


Figure 5-4 Proposed Raw Water Pipeline Alternatives 2A

Water pipelines can be installed underwater and is utilized for intakes and river crossings. For the Indian Hill Reservoir pipeline, it is possible to route the new pipeline through the Upper and Lower Artichoke Reservoirs rather than the proposed cross country or roadways. Installation could be accomplished by floating pre-assembled HDPE pipe segments with weighted anchors and sinking the pipe within the reservoir. Construction would require one or more staging areas depending on the number of segments and would utilize cranes and boats for installation. The Upper and Lower Artichoke Reservoirs are relatively shallow reservoirs with depths of only 4 to 5 feet in many areas assuming maximum reservoir levels. Excavation would be required for connections at each end of the reservoirs, and potentially to cross Upper Artichoke Dam and areas of the reservoirs with shallower depths. Locating the pipeline within the reservoirs would have the following considerations/risks:

- Thermal changes due to the relatively shallow depths
  - Increased water temperature during the summer
  - Pipe contraction and expansion
- Potential for pipeline exposure during droughts
- Access issues for pipe repairs
- Potential for freezing temperatures with limited cover during winter months
- Additional permitting requirements for work within the reservoir and possible trenching for connection points at either end of pipeline
- Routing to cross the Upper Artichoke Dam without compromising the dam.
- Piping upstream of the Upper Artichoke Reservoir would still require road or cross-country installation.

Installation of the water main within the reservoir would provide the most direct path to connect to the Lower Artichoke Pump Station, with a potential reduction of approximately 1,000 LF of pipeline. However, due to the design and operations consideration/risks, this option was not considered further in this evaluation.

5.3.1.1 Easements

Alternatives 1 through 4, including 2A, are considered "cross country routes" which include proposed piping along private property (Table 5-6). Alternatives 5 and 6 are constructed within existing roadways and should not require any easements. Cross country construction will require obtaining easements from each property owner along the pipeline route.

Additionally, one of the routes crosses a property owned by the Essex Country Greenbelt Association, which is considered public open space subject to protection under Article 97 of the Amendments of the Massachusetts Constitution. Installation of a new water line within that property would require local and state review, including state legislation. Article 97 provides that certain properties acquired as natural resource land cannot be used or disposed of for other purposes, except by a law enacted by a two-thirds vote of each branch of the Legislature.

In addition, disposition of land, including the granting of easements for underground infrastructure across protected lands, requires review of the project in accordance with the Executive Office of Energy and Environmental Affairs (EEA) Article 97 Land Disposition Policy, which requires local and state approvals, include review under the Massachusetts Environmental Policy Act (MEPA). As part of the disposition process, the project proponent has to prove that there is no feasible alternative to use of the protected land, and that mitigation includes protection of land equal in value to the Article 97 land being disposed of. The process can take approximately two years, and the outcome is not guaranteed.

Construction and permanent access easements are typically associated with monetary fees to each property owner. Therefore, the permitting process for Article 97 lands and obtaining easements could increase the cost of Alternatives 1-4. Easement costs are not included in the conceptual Opinion of Probable Construction Costs (OPCCs), as specific pricing will be negotiated with each property owner.

TABLE 5-6
Easements Required

Owner	Alt. 1	Alt. 2	Alt. 2A	Alt. 3	Alt. 4	Alt. 5	Alt. 6
Essex County Greenbelt Association	X	X	X	X	X		
Private Land Owner	X	X	X	X	X		

5.3.1.2 Wetlands

Each proposed route includes construction within 100 feet of the Indian Hill Reservoir and several alternatives include construction within additional wetland resource areas as identified on the MassGIS Oliver system. For conceptual layout development as outlined herein, wetland resource areas were not field verified. Construction within resource areas or the jurisdictional buffer zones of resource areas (reservoir, bordering vegetated wetland, vernal pool, pond, and streams) will require wetland permitting.

Wetland permitting will require at a minimum a Notice of Intent filed with the local Conservation Commission for the project. The extent of the wetland permitting will be determined after a wetland resource area delineation is complete and a final route is selected. Additional permitting could include Self-Verification or Pre-Construction Notification from the Army Corps of Engineers, a 404 Water Quality Certification from MassDEP and MEPA review. Impacts to bordering vegetated wetlands of 5,000 sf or greater requires additional regulatory review. This additional regulatory review can increase the cost of the project, including the cost of mitigation for this impact, and can increase the review timeframe for a project by several months to a year or more. The permitting processes also have public notice requirements; and comments received by the public need to be considered and addressed. Permitting agencies will also require an alternatives analysis identifying how resource areas impacts were avoided, minimized and mitigated for. If an alternative has less resource area impacts, a strong case is needed why the more impactful project is proposed.

Alternative 2A assumes horizontal directional drilling under the wetland between Indian Hill Street and the Reservoir's outlet. Work would still be required within the 100-foot buffer zone to resource areas for the piping connection. Alternative 2A was developed at the City requests to review a gravity option and to identify if there would be cost savings by eliminating the construction and operations expenses of a pump station.

Alternatives 5 and 6 would avoid additional wetland impacts by constructing the raw water transmission main within existing roadways.

5.3.1.3 Indian Hill and Lower Artichoke Raw Water Pump Stations

The Lower Artichoke Pump Station currently pumps water from the Lower Artichoke Reservoir to the WTP. A pump station is required at either the Lower Artichoke or Indian Hill Reservoir. A conceptual review of the pipeline profile for each alternative was evaluated to determine whether water from the Indian Hill Reservoir can flow by gravity to the existing Raw Water Pump Station or whether a new pump station will be required to pump the water to the existing raw water transmission main. All alternatives with the exception of Alternative 2A would require a pump station at the Indian Hill Reservoir.

5.3.1.4 Indian Hill Reservoir Pump Station

It was assumed for all options requiring a new Indian Hill Pump Station that the pumps would be sized with enough hydraulic head to pump directly to the Water Treatment Plant (WTP) and would connect to the existing raw water pipeline downstream of the Lower Artichoke Pump Station for added redundancy and to avoid the operational complexities of pumping in series. The Lower Artichoke Pump Station utilizes vertical turbine pumps installed in pump cans open to the atmosphere. Due to the hydraulic elevation of Indian Hill, the pump station could flood if the water is pumped in series without complex controls to reduce the Indian Hill hydraulic gradeline. The Lower Artichoke Pump Station could still be utilized to blend Lower Artichoke water with water from the Indian Hill Reservoir based on available water supplies and quality in each reservoir. This blending can be used to maximize the available water and optimize the water quality if needed.

A redundant pump station would provide the following advantages:

- Ability to remove the existing pump station from service for maintenance.
- Redundancy during potential flooding events in case of pump station inundation.
- Flexibility for pipeline alignments and profile compared to gravity flow.
- Smaller diameter water main compared to gravity flow.
- Simplified operation compared to operating pumps in series.
- Better efficiency by avoiding pressure reducing valves at the Lower Artichoke Pump Station to maintain the required water operating level for the vertical turbine pumps.

- Alternatively, a pump station could be sized to overcome the head needed to flow by gravity to the existing Lower Artichoke Pump Station. However, this would limit the alignment options and would require upsizing the water main to limit head loss. Pumping in series will add inefficiencies to the system and operational complexities for controls. The existing raw water pumps are vertical turbine pumps. Pressure reducing valves would be required due to the hydraulic grade line at the Lower Artichoke Pump Station being approximately 10 to 30 feet above the maximize operating level of the pumps depending on the flow rate and Indian Hill Reservoir water level.

5.3.1.5 Lower Artichoke Pump Station

Alternative 2A can utilize gravity flow all the way from the Indian Hill Reservoir to the Lower Artichoke Pump Station. This alternative would require the use of the existing Lower Artichoke Pump Station for pumping to the WTP. In order to utilize the Lower Artichoke Pump Station, the pipeline design must maintain the hydraulic gradeline above the pipeline elevations. To maintain an elevated hydraulic gradeline, head loss must be minimized. The following design assumptions were made to maintain the hydraulic gradeline:

- The pipeline profile was based on maintaining the hydraulic grade line 3’ above the pipeline in order to maintain full pipe flow and to account for variations in the ground surface elevations.
- A 24” pipeline was assumed from the existing Indian Hill outlet to Indian Hill Street. It was assumed that this segment would be installed via horizontal directional drilling to minimize wetland impacts and achieve the necessary pipeline depth.
- The pipeline transitions to 36” at Indian Hill Street to minimize head loss and to minimize excavation depths. Higher head loss with maintaining a 24” pipe would lower the hydraulic grade line and require deeper excavations to maintain the hydraulic grade line higher than the pipe. Deep excavation would still be required in one location with a 36” pipe with an assumed pipeline invert at approximately 10’ below grade.
- As the pipeline approaches the Lower Artichoke Pump Station, the ground surface elevations decreases resulting in a larger difference between the hydraulic grade line and the pipe elevation. This allows the pipeline to be reduced to 20” to reduce construction costs. The existing raw water pumps are vertical turbine pumps and a maximum water surface elevation must be maintained to avoid overflowing the pump cans. The hydraulic grade line is estimated to be above the maximum water surface elevation for the pumps even at the minimum water surface elevation in the Indian Hill Reservoir. The additional head loss from reducing to a 20” pipe also lowers the hydraulic grade line and minimizes the necessary pressure reduction at the Lower Artichoke Pump Station.

Geotechnical investigations will be required during design to determine if ledge exists along the align that will increase the cost of construction.

With modifications to the Lower Artichoke Pump Station inlet piping, the pump station could be utilized to pump from the Lower Artichoke Reservoir, Indian Hill Reservoir, or a combination of both. By installing new pump header piping with isolation valves between each pump, a combination of 1, 2 or 3 pumps could be supplied from either reservoir depending on the necessary blending ratio.

The primary flow direction for all options is assumed to be from Indian Hill Reservoir to the WTP. However, once the pipeline is installed, it would be possible to utilize the Lower Artichoke Pump Station to pump water to the Upper Artichoke or Indian Hill Reservoir depending on water volumes in each reservoir. Indian Hill Reservoir has the slowest recharge rate of the three reservoirs due to the limited size of the watershed. Pumping to Upper Artichoke would likely be possible with the existing pumps. However, a detailed hydraulic evaluation and possible pump station modifications may be required to pump to the Indian Hill Reservoir due to the higher elevation of the reservoir. Historically, the Upper and Lower Artichoke Reservoirs have had higher phosphate concentrations, which increases the potential for algal blooms. Water quality of the three reservoirs should be monitored and evaluated prior to moving water to the Indian Hill Reservoir.

5.3.1.6 Indian Hill Reservoir Intake and Outlet

The Indian Hill Reservoir has two intakes from the reservoir into the gate house – an 18" mid-level at elevation 49.3' and a 24" low-level at elevation 38.6'. The gate house has a 36" RCP outlet at elevation 37.2' that runs approximately 50' to the dam's toe of slope at elevation 36.9'.

Alternative 2A assumes connecting to the existing outlet at the toe of slope and flowing by gravity to the Lower Artichoke Pump Station. Each of the other Alternatives will require their own pump station and will include a new intake within the Indian Hill Reservoir.

5.3.1.7 Crossing Upper Artichoke

Alternatives 3 and 6 include crossing the width of the Upper Artichoke Reservoir in order to get to get to the opposite side so the water main can continue along the eastern shore of the Lower Artichoke. This alternatives analysis has assumed that crossing of the dam will be completed by floating and sinking an HDPE pipe across the reservoir upstream of the Upper Artichoke Dam. Additional analysis will be required to confirm the pipeline alignment will not impact the dam.

5.3.1.8 Connection to the Upper Artichoke Dam

The Indian Hill Reservoir is the largest of the three reservoirs in volume, but it has the smallest watershed, and therefore the longest recharge time, of the three reservoirs. Indian Hill is generally the cleanest of the three reservoirs but will be impacted more by droughts due to the slower recharge rate.

The Upper Artichoke has historically had the worst water quality. Having the ability to pump directly from the Upper Artichoke Reservoir would provide additional operational flexibility during a flooding event if only the Lower Artichoke is impacted or could provide flexibility to treat the Lower Artichoke for algal blooms without impacting the water supply to the WTP. Construction of the raw water main from the Indian Hill Reservoir past the Upper Artichoke Reservoir dam can be provided by Alternatives 1, 2, 2A, 3, and 6. An additional raw water intake for the Upper Artichoke Reservoir could be constructed. The existing pumps cannot pull a suction and water must flow by gravity to the pump station unless the pumps are upgraded. Due to the reservoir elevation and the required pump station water elevations, construction of the pipeline would have to be immediately adjacent to the reservoir or will require deeper excavations to maintain the hydraulic profile for the Lower Artichoke Pump Station given the steep slopes adjacent to the reservoir.

If an intake is added for the Upper Artichoke Reservoir, the pump station could only pump Upper Artichoke or Indian Hill Reservoir. Due to the higher hydraulic gradeline for the Indian Hill Reservoir, blending Upper Artichoke and Indian Hill Reservoir by gravity would not be possible. With modifications to the Lower Artichoke Pump Station inlet piping, the pump station could be utilized to pump from the Lower Artichoke or Upper Artichoke/Indian Hill Reservoir, or a combination of both. By installing new pump header piping with isolation valves between each pump, a combination of 1, 2 or 3 pumps could be supplied from either reservoir depending on the necessary blending ratio.

The alignment of Alternatives 4 and 5 is along Route 113 and would not provide access to the Upper Artichoke Reservoir.

5.3.1.9 Bridge Crossing

Alternatives 5 and 6 include construction of the water main along the MassDOT Route 113 highway and crossing the Artichoke River. This alternatives analysis has assumed that crossing of the river will be completed by hanging the water main from the existing MassDOT bridge crossing the Artichoke River along Route 113.

Construction of the water main along Route 113 will require coordination and approval of the water main attachments by MassDOT and a MassDOT State Highway Access Permit. Correspondence with MassDOT should be conducted to review the feasibility of attaching a water main to the existing bridge. In the event that MassDOT opposes the attachment to the bridge, an alternative means to crossing the river will be required, such as horizontal directional drilling below the river.

5.3.1.10 Summary

Table 5-7 provides a summary of the major considerations and challenges noted above as they relate to each alternative.

TABLE 5-7
New Transmission Line Alternatives - Matrix of Major Considerations and Challenges

	Alternative						
	1	2	2A	3	4	5	6
Pipeline Length (LF)	23,100	20,600	21,800	16,800	16,650	17,350	17,500
Easements Required	X	X	X	X	X		
Additional Wetlands Impacts and Permitting	X	X	X	X	X		
New Pump Station at Indian Hill Reservoir	X	X		X	X	X	X
Crossing Upper Artichoke Reservoir				X			X
Access to Upper Artichoke Reservoir	X	X	X	X			X
Artichoke River Crossing (at Route 113)					X	X	
Modification to Lower Artichoke Pump Station			X				

5.3.2 Conceptual Opinion of Probable Construction Costs

The conceptual opinion of probable construction cost (OPCC) for the water main alternatives is based on Class 4 level construction cost estimates, as defined by the Association for the Advancement of Cost Engineering (AACE) International Recommended Practices and Standards. The expected accuracy range of a Class 4 estimate is between -30% to +50%. The presented costs are based on the following assumptions:

- Water mains will be 16” in diameter for pressure pipe
- Water mains will be between 20” and 36” for gravity pipe
- Gravity main will flow by gravity from Indian Hill but the pipe will flow full and be under pressure. Pipe elevations were assumed to be a minimum of 3’ below the hydraulic grade line.
- Over-excavation costs were assumed for any pipeline location with greater than 5’ of excavation to top of pipe.
- Geotechnical investigations will be required to confirm feasibility of horizontal directional drills and over excavation for gravity flow.
- Alternative 2A will connect to the existing Indian Hill Reservoir outlet piping and will not require a new intake in the Indian Hill Reservoir.
- Important: Costs associated with easements – including field survey, drafting of legal documents, legal fees, and purchase costs – and Article 97 compliance are not included.
- Cost multipliers:

- General Conditions: 15%
- Contingency: 25%
- Design and Construction Phase Engineering: 20%

Table 5-8 summarizes the OPCC for all seven alternatives. Detailed OPCCs are provided in Appendix P. Costs for the seven alternatives ranged from $13M to $16M for construction and engineering costs. Alternative 2A is the only option that does not require a new pump station at the Indian Hill Reservoir. This option was not the lowest capital cost option but would reduce annual operations and maintenance costs by only having a single raw water pump station to operate and maintain. The costs below do not include the costs of easements and Article 97 compliance that would increase the costs associated with all alternatives, except Alternatives 5 and 6.

TABLE 5-8
Opinion of Probable Construction Cost

Alternative	OPCC
Alternative 1 – Cross Country/ South Street/ Turkey Hill Road	$15,900,000
Alternative 2 – Cross Country/ Pikes Br Rd/ Turkey Hill Rd	$14,700,000
Alternative 2A – Gravity Flow with Cross Country/ Pikes Br Rd/ Turkey Hill Rd	$13,600,000
Alternative 3 - Cross Country/ Pikes Br Rd/ Garden Rd/ Middle St	$13,300,000
Alternative 4 - Cross Country/ Pikes Br Rd/ Garden St/Rt 113	$13,300,000
Alternative 5 - Moulton St/ Cherry Hill St/ Garden St/ Rt 113	$13,900,000
Alternative 6 - Moulton St/ Cherry Hill St/ Garden St/ Middles St/ Cross Country	$13,600,000

5.3.3 Conclusions and Recommendations

The only existing intake for the three surface water reservoirs is within the Lower Artichoke Reservoir – the most-downstream location possible. Due to the elevation of the Lower Reservoir Dam and its hydraulic connection to the Merrimack River, the intake is susceptible to backflow from the Merrimack River during certain storm events. The WTP does not have the ability to treat the brackish and contaminated water that could overtop the dam. To provide water during a potential flooding events one of the following options must be implemented 1) additional reservoir intakes, 2) dam improvements to prevent overtopping, or 3) water treatment plant upgrades to treat brackish and contaminated water. This section evaluated options for an additional reservoir intake. Dam improvement options are presented in Section 5.2 and water treatment improvement are presented in the Section 5.4.

The Upper and Lower Artichoke Reservoirs also have significant water quality concerns, especially for algal growth, that could compromise the two lower reservoirs. The Indian Hill Reservoir is a deeper reservoir with historically the highest water quality of the three reservoirs. However, the Indian Hill Reservoir experienced an algal bloom in 2020. Having additional intakes within the Upper Artichoke or Indian Hill Reservoir would provide additional redundancy and reliability for future water quality or flooding issues.

Seven alternatives were evaluated for potential raw water transmission mains that could supply the WTP with water directly from the Indian Hill Reservoir or the Upper Artichoke and Indian Hill Reservoirs. Table 5-9 presents the considerations used to evaluate each alternative. Based on the evaluated criteria, Alternative 6 is the recommended alternative based on the following:

- Alignment is primarily within existing roadways, which eliminates the need for easements, reduces maintenance costs associated with cross county alignments, and reduces potential wetland impacts.
- A pump station at the Indian Hill Reservoir will be required but this will allow for improved operational flexibility and reliability in the event that the Lower Artichoke Pump Station is unavailable.
- Access to the Upper Artichoke Reservoir would also be possible for flexibility to utilize any one of the three reservoirs. Additional evaluations of pump modifications or pipeline elevations will be required during detailed design to confirm the ability to pump directly from Upper Artichoke Reservoir.

TABLE 5-9
Alternatives Comparison

Alternative	**1**	**2**	**2A**	**3**	**4**	**5**	**6**
Pipeline Length (LF)	23,100	20,600	21,800	16,800	16,650	17,350	17,500
Easement Required	X	X	X	X	X		
Additional Wetlands Impacts and Permitting	X	X	X	X	X		
Raw Water Pump Station	X	X		X	X	X	X
Crossing Upper Artichoke Reservoir				X			X
Access to Upper Artichoke Reservoir	X	X	X	X			X
Bridge Crossing and MassDOT Permitting					X	X	
Opinion of Probable Construction Cost	$15.9M	$14.7M	$13.6M	$13.3M	$13.3M	$13.9M	$13.6M

5.4 New Water Supply/ Desalination Plant

Newburyport staff has indicated that the City has searched for additional water supplies within Newburyport and Newbury and has not identified any viable groundwater sources. As noted in Section 2, the Town of West Newbury has identified a potential groundwater source off Dole Place in the western end of West Newbury. Newburyport could work with West Newbury to develop a well at this location.

Another option would be to permit a withdrawal from the Merrimack River. Tighe & Bond researched treatment being used on upstream public water supply withdrawals from the Merrimack River and this information is summarized in Appendix Q. However, these water supplies are located upstream of the tidal influence. Should Newburyport pursue a withdrawal from the Merrimack River within the City limits, a desalination plant utilizing reverse osmosis (RO) or other desalinization technologies would be required.

For desalination treatment, a new withdrawal and brine disposal would need to be permitted, land acquired for the new treatment facility, and a new desalination plant constructed. The cost for a desalination plant would depend on the water quality at the location of the intake. Lower salinity brackish water is less expensive to treat than saltwater. Conceptual costs based on available RO costs curves for a 4MGD desalination plant range from $13M for brackish water RO to $28M for saltwater RO. These costs include intake construction, brine disposal, site preparation, valves and piping, auxiliary equipment, and discharge systems. Conceptual annual operation and maintenance (O&M) costs for energy and chemical usage range from $0.77 per 1,000 gallons of treated for a brackish RO to $1.5 per 1,000 gallons treated for a saltwater RO system. Capital and annual O&M costs were based upon *Technology Review and Data Analysis for Cost Assessment of Water Treatment Systems* (Bhojwani et al., 2019) and *Cost Modeling of Desalination Systems* (Huehmer et al. 2011).

Tighe & Bond did not assess upgrades to the existing WTP to address either the impact of an algal bloom or a backwater event from the Merrimack River. As Newburyport looks to address other potential contaminants, such as PFAS, the treatment evaluation should also consider other potential contaminants.

5.5 Resiliency Recommendations

The sections above outlined several options to address sea level rise and water quality concerns within the reservoir system. The City will have to assess the value of these alternatives to identify which makes the most sense to pursue. The new raw water transmission main can supply water to the WTP bypassing the Artichoke Reservoir in the case of a breach from the Merrimack River or an algal bloom. This alternative has a higher cost but is anticipated to have fewer permitting hurdles than the dam reconfiguration.

The reconfiguration of the Lower Artichoke Reservoir Dam would allow the City to protect the water supply the Merrimack River. Increasing the height of the dam provides an opportunity to widen the dam, which will also improve the dam stability, however, this option would require significant environmental permitting and acquisition of land for the new embankment configuration.

The City may choose to undertake both a new water transmission line, to provide redundancy to the water supply system, and improvements to the Lower Artichoke Reservoir Dam to protect the water supply from a backwater event.

A high-level comparison of the alternatives reviewed is provided in Table 5-10.

TABLE 5-10
Resiliency Alternatives Pros and Cons

Alternative	Addresses SLR	Addresses Water Quality	Addresses Water Quantity	Minimizes Permitting	Provides Redundancy	Allows for use of All Reservoirs	No Land Acquisition	Cost
New Raw Water Transmission Main (Alternative 6)	+	+		+	+	+	+	$13.3-$15.9 M
Lower Artichoke Dam Improvements	+	+				+		$6.9M
Lower Artichoke Dam Improvements – Extension	+	+				+		$8.0M
Upper Artichoke Dam Improvements	+	+					+	$4.4M
Merrimack River Withdrawal	+	+	+		+			$13M-$28M

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APPENDIX A

CITY OF NEWBURYPORT
DEPARTMENT OF PUBLIC SERVICES
16A PERRY WAY
NEWBURYPORT, MA 01950

ANTHONY J. FURNARI, DIRECTOR
JAMIE TUCCOLO, DEPUTY DIRECTOR/DIRECTOR OF OPERATIONS

PHONE: 978-465-4463/4464
FAX : 978 462 2063

MEMORANDUM

DATE: March 4, 2021

TO: Tom Cuscik, WTP Operator

FROM: Jon-Eric White, City Engineer

COPY: Tracy Adamski, Tighe and Bond
James Collins, Tighe and Bond

SUBJECT: **DISCREPANCIES IN LAST YIELD REPORT FOR RESERVOIRS**

The purpose of this memo is to summarize the discrepancies I observed in AECOM's 2018 Yield Estimate Report for our 3 largest reservoirs. The outcome of this memo will provide a more realistic maximum usable storage volume for you to use as needed.

FROM AECOM'S 2018 YIELD REPORT (modified to provide a column for Low Water Elevation):
Maximum Usable Storage Per Reservoir (elevations in feet NAVD88 Datum):

Reservoir	Max. Water Surface Elevation	Intake Pipe Invert Elevation	Intake Pipe Diameter (ft.)	Low Water Elevation	Maximum Usable Storage (MG)
Indian Hill	61.5	38.5	2.0	43.0	673.9
Upper Artichoke	13.6	2.0	2.0	4.0	273.1
Lower Artichoke	9.6	3.0	Vertical pipe	(Info not provided)	58.2

Screenshots of spreadsheet determining these calcs are included on p.3.

I noticed errors in the above table and in the 2018 Report as follows:

1. P. 15, 2nd bullet: they reference 1.5' of submergence but AECOM confirmed to me last week that this is a mistake and it should have been 2.5'. So the "Low Water Elev" of 43.0 ends up being correct but they did not use 43.0 to determine their Max. Usable Storage. They used elevation 43.6' for the Low Water Elev. to come up with the Max. Usable Storage of 673.9MG.
2. The Upper Artichoke spillway elevation is 12.4' so using 13.6' for Max Water Surface Elev is incorrect.
3. The Lower Artichoke spillway elevation is 8.8' so using 9.6' for Max Water Surface Elev is incorrect.
4. The Artichoke Pump Station has a minimum water surface elevation of 4.1' NAVD88, per the design drawings. So the volume in the table above is incorrect.

CORRECTED USABLE STORAGE PER RESERVOIR (elevations in feet NAVD88 Datum):

Reservoir	Max. Water Surface Elevation	Intake Pipe Invert Elevation	Intake Pipe Diameter (ft.)	Recommended Low Water Elevation	Maximum Usable Storage (MG)
Indian Hill	61.5	38.5	2.0	40.5	755
Upper Artichoke	12.4	2.0	2.0	4.0	269
Lower Artichoke	8.8	3.0	Vertical pipe	4.1	49.9

END RESULT:

Reservoir	Prior Maximum Usable Storage (MG)	Maximum Usable Storage (MG)	Net Change (MG)
Indian Hill	673.9	755	+81.1
Upper Artichoke	273.1	269	-4.1
Lower Artichoke	58.2	49.9	-8.3
TOTAL	1,005.2	1,073.9	+68.7

FYI, the permitted firm yield (DEP Permit # 9P-3-13-206.01, executed 11/30/17) is 2.20 mgd but the firm yield in the AECOM Report is 2.29 mgd, which may explain why I've been hearing different numbers.

CONCLUSION:

This is good news.

- You have approximately 69MG of usable storage that is not being accounted for in the last Yield Report *when the reservoirs reach the top of the intake pipes and the Lower Artichoke reaches Elev. 4.1'*.
- You can assume you have another 34MG when the reservoirs reach the inverts of the intake pipes, for a total of 103MG.
- Tighe and Bond is using the firm yield, safe yield, and maximum usable storage volumes as published in the AECOM 2018 Report for their Watershed Protection Resiliency Plan report coming out this month. There is no need for them to recalculate these numbers. The end result is we have additional storage available.
- My recommendation is to reserve this undocumented volume when we'll need it in times of drought. *Changes in climate will likely result in extended and more severe droughts.*

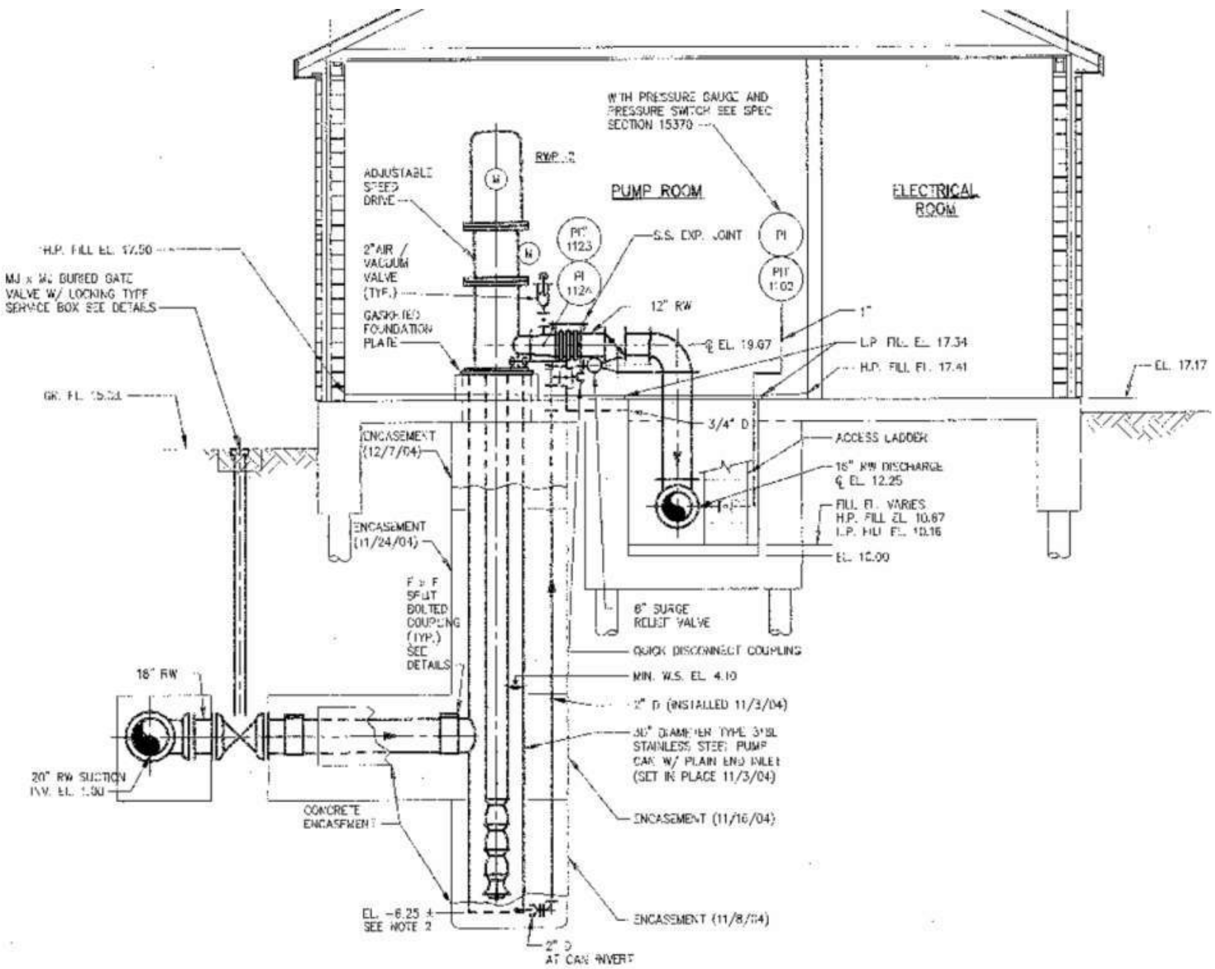
SCREENSHOTS BELOW ARE FROM THE BATHYMETRIC CALCS MADE BY CR ENVIRONMENTAL, INC., AND USED BY AECOM, AND SLIGHLY EDITED BY ME TO PROVIDE COMMENTS AND VOLUME CALCS. MANY ROWS HAVE BEEN "HIDDEN" FOR CLARITY PURPOSES.

INDIAN HILL						
Elevation (NAVD88 - ft)	Volume (ft^3)	Planar Area (ft^2)	Surface Area (ft^2)	Volume (Gallons)	usable volume	
61.5	105,589,400	5,606,000	5,626,100	789,863,300		THIS ELEVATION WAS USED IN AECOM'S 2018 REPORT AND WAS VERIFIED BY FIELD WORK LEVEL-RUNS BY HANCOCK SURVEY IN 2020.
43.6	15,497,500	4,147,000	4,148,700	115,929,100	673,934,200	VOLUME USED IN AECOM'S 2018 REPORT. BUT IT APPEARS TO BE AN ERROR BASED ON THEIR NARRATIVE IN THE REPORT. THEY SHOULD HAVE USED 38.5' INVERT + 2' PIPE + 2.5' ABOVE PIPE FOR LOW WATER ELEV, OR 43.0'
43.0	13,060,300	3,966,400	3,967,800	97,697,500	692,165,800	AECOM'S 2018 REPORT REFERRED TO LOW WATER ELEV OF 43.0 BUT THIS IS NOT THE VOLUME THEY PUT IN THEIR TABLE. THEY USED 43.6' ELEV. FOR THE LOW WATER ELEVATION, NOT SURE WHY.
40.6	4,672,700	2,954,200	2,954,800	34,954,300	754,909,000	TOP OF PIPE VOLUME.
38.6	443,300	844,200	844,400	3,315,800		THIS ELEVATION WAS USED IN AECOM'S 2018 REPORT AND WAS VERIFIED BY FIELD WORK LEVEL-RUNS BY HANCOCK SURVEY IN 2020.

UPPER ARTICHOKE						
Elevation (NAVD88 - ft)	Volume (ft^3)	Planar Area (ft^2)	Surface Area (ft^2)	Volume (Gallons)		
12.4	34,540,500	5,414,600	5,421,600	258,381,200	273,058,100	Vol @ EL. 12.4 - vol @ El. 4 (elev. 2+2' to get to top of pipe, see AECOM report) + vol of Upper Tributary @ elev 13.0
4.0	317,100	701,600	701,900	2,372,200	269,441,800	Vol @ EL. 12.4 - vol @ El. 4 (elev. 2+2' to get to top of pipe, see AECOM report) + vol of Upper Tributary @ elev 12.4
2.0	6,400	14,700	14,700	47,500	outlet elev.	
UPPER TRIBUTARY:						
Elevation (NAVD88 - ft)	Volume (ft^3)	Planar Area (ft^2)	Surface Area (ft^2)	Volume (Gallons)		
13.0	2,279,100	894,700	895,600	17,049,100		
12.4	1,795,700	711,500	712,100	13,432,800		

LOWER ARTICHOKE						
Elevation (NAVD88 - ft)	Volume (ft^3)	Planar Area (ft^2)	Surface Area (ft^2)	Volume (Gallons)	MAX USABLE VOLUME	
8.8	8,463,400	1,595,600	1,600,600	63,310,700		
4.2	1,794,400	1,153,300	1,154,500	13,423,200	49,887,500	Artichoke Pump Station has a minimum water surface elevation of 4.1'.
3.0	684,800	633,200	633,800	5,122,900	58,187,800	MAXIMUM USABLE STORAGE USED IN AECOM'S 2018 REPORT = EL. 8.8 VOLUME - EL. 3.0 VOLUME (INTAKE ELEV.)

Detail 1, Sheet M-3, Water Works Improvements Phase I, by Metcalf & Eddy, dated 2004:



SECTION 1

CITY OF NEWBURYPORT INDIAN HILL AND ARTICHOKE RESERVOIRS
STORAGE CAPACITIES FOR YIELD CALCULATIONS*

RESERVOIR	MAX. WATER SURFACE ELEV.	INTAKE PIPE INVERT ELEV.	LOW WATER ELEV. USED FOR YIELD CALCS	VOLUME (MG)
INDIAN HILL	61.5	38.5	42.0	720.4
UPPER ARTICHOKE	12.4	2.0	4.0	269.4
LOWER ARTICHOKE	8.8	3.0	4.0	51.6
TOTAL STORAGE VOLUME:				1,041.4

*NOTES:
1. VOLUMES ARE BASED ON BATHYMETRIC SURVEY PERFORMED BY CR
2. ELEVATIONS ARE IN FEET USING NAVD 88 DATUM.

Tighe&Bond

APPENDIX B

OFFICE OF
WATER COMMISSIONERS
CITY HALL
NEWBURYPORT, MASSACHUSETTS 01950

March 20, 1980

Mr. Charles D. Courtemanche
Board of Water Commissioners
Town Hall
West Newbury, Ma. 01830

Dear Mr. Courtemanche,

Enclosed please find two (2) copies of the contract for the sale of water from the City of Newburyport to the Town of West Newbury. If there are any questions with regard to this matter, please feel free to call or contact the Water Department Office. (462-2991)

Yours truly,

John N. Pritchard, Manager
Newburyport Water Department

dbh/JNP

AGREEMENT

BETWEEN

CITY OF NEWBURYPORT

AND

TOWN OF WEST NEWBURY

1. The City of Newburyport, hereinafter called the CITY, and the Town of West Newbury, hereinafter called the TOWN, mutually agree to the terms and conditions of this Contract for the sale of water for public use and consumption.

2. The CITY hereby agrees to sell not more than 175,000 gallons of water per day to the TOWN until the Artichoke Reservoir Expansion Project is complete and in use, and subject to the availability of such water. After said completion date, the CITY further agrees to adjust the present limit of 175,000 gallons of water per day based upon the increased availability of water from said Reservoir expansion. The sale of said water shall be at a negotiable rate not to exceed the commercial rate set for CITY users and established by the CITY BOARD OF WATER COMMISSIONERS.

3. All necessary pipelines, meters, meter pits and related appurtenances necessary to provide interconnection between the CITY and the TOWN distribution system shall be subject to the standard of the CITY and cost thereof shall be borne by the TOWN.

4. A meter and meter pit shall be provided at approximately the CITY-TOWN line within the boundaries of the CITY and shall be owned and controlled by the CITY.

5. Monthly billing shall be made to the TOWN by the CITY based on readings taken by the CITY and verified by the TOWN at their option.

6. As future available supplies increase or decrease, and the demand for said supplies to the TOWN increases or decreases, the limit of 175,000 gallons of water per day may be adjusted based on mutual agreement by both parties, and pursuant to the provisions contained in paragraph (2) above.

7. In the event adequate water is not available as a result of emergency or drought or any other conditions, water will be supplied proportionally to all users, however, with priority given to CITY residents, with a minimum quantity supplied for all customers and emergency users.

8. The TOWN agrees to save harmless the CITY from future loss or damage caused as a result of any misfeasance, malfeasance, or non-feasance of said TOWN within the boundaries of said TOWN.

9. In the event either party fails to satisfy any provision of this agreement, said party shall have thirty (30) days in which to satisfy said provision.

10. The term of this agreement shall be five (5) years, and thereafter shall continue for succeeding three-year periods unless one party notifies the other party in writing at least sixty (60) days before the expiration date of any three-year period, of its desire to terminate the contract on that expiration date.

11. This agreement shall terminate prior to the completion of the first five-year period upon the following:

a) upon mutual agreement of the CITY and TOWN;

b) at the option of either the CITY or TOWN, if the other fails to comply with provisions of this agreement.

12. The contract may be amended at any time by mutual agreement of the CITY BOARD OF WATER COMMISSIONERS and the TOWN BOARD OF WATER COMMISSIONERS.

IN WITNESS WHEREOF, the parties have hereunto set their hands and seals this tenth (10th) day of March 1980.

TOWN OF WEST NEWBURY
BOARD OF WATER COMMISSIONERS:

CITY OF NEWBURYPORT
BOARD OF WATER COMMISSIONERS

Witnessed:

Witnessed:

Tighe&Bond

APPENDIX C

SECTION XIX. - WATER RESOURCE PROTECTION DISTRICT

XIX-A - Purpose of district.

The purpose of this water resource protection district is:

1. To promote the health, safety, and general welfare of the community by ensuring an adequate quantity and highest quality of water possible for residents, institutions and businesses of the City of Newburyport.
2. To preserve and protect existing and potential watersheds and aquifers for drinking water supplies.
3. To prevent temporary and permanent contamination in the water resource protection district.
4. To protect the community from the detrimental use and development of land and water within the water protection district.

(Ord. of 7-27-98(5); Ord. of 10-27-03)

XIX-B - Scope of authority.

The water resource protection district is an overlay district superimposed on the zoning districts. This overlay district shall apply to all new construction, reconstruction, or expansion of existing buildings and new or expanded uses. Applicable activities or uses which fall within the water resource protection district shall comply with the requirements of this district as well as with the underlying zoning. Uses that are prohibited in the underlying zoning districts shall not be allowed in the water resource protection district.

(Ord. of 7-27-98(5))

XIX-C - Definitions.

For the purpose of this ordinance [section], the following words and phrases shall have the following meanings:

Aquifer. Geologic formation composed of rock, sand, or gravel that contains significant amounts of potentially recoverable water.

Disposal. The deposit, injection, dumping, spilling, leaking, incineration, discharge, or placing of any material into or on any land or surface water or groundwater so that such material or any constituents thereof may enter the environment or be emitted into the air or discharged into any waters subject to this ordinance.

Disturbance. Activities including, but not limited to land clearing and grading, tree and shrub removal, mowing, burning, spraying, grazing, soil and gravel removal, all construction and any other unlawful or disruptive activities.

Groundwater. All water beneath the surface of the ground in a saturated zone.

Impervious. Material or structure on, above, or below the ground that does not allow precipitation or surface water to penetrate directly into the soil.

Mining. The removal or relocation of geological materials such as topsoil, sand, gravel, metallic ores, or bedrock.

Recharge areas. Areas that collect precipitation or surface water and transmit it to aquifers.

Surface water. All water open to the atmosphere and subject to surface runoff, including but not limited to rivers, streams, lakes, ponds, springs, impoundments, estuaries, wetlands, coastal waters, and vernal pools.

Water resource protection district. The zoning district defined to overlay other zoning districts in the city. The water resource protection district includes three distinct watershed zones for surface water sources: Zone A, Zone B and Zone C. The water resource protection district includes two distinct zones for groundwater sources: Zone I and Zone II.

Toxic or hazardous material. Any substance or mixture of substances which, because of its physical, chemical or infectious characteristics, posing a significant actual or potential hazard to water supply or to human health if such substance or mixture were discharged to land or water of the city. Toxic or hazardous materials include, without limitation, synthetic organic chemicals, petroleum products, heavy metals, radioactive or infectious wastes, acids and alkalis, and all substances defined as toxic or hazardous under M.G.L.A. c. 21C and 21E, and 310 CMR 30.00 as well as such products as solvents and thinners in quantities greater than those associated with normal household use.

Tributary. Any body of running, or intermittently running, water which moves in a definite channel, naturally or artificially created, in the ground due to a hydraulic gradient, and which ultimately flows into a Class A surface water source, as defined in 314 CMR 4.05(3)(a).

Watershed. Land area bounded by a ridgeline of higher elevation, or drainage divide, from which surface runoff and groundwater flow downgradient into streams, ponds, reservoirs, wetlands, and aquifers. An aquifer is located within a watershed and is recharged by precipitation falling on watershed land.

The watershed zones are generally defined by the direction of the flow of water. These zones are specifically shown on the delineation map identified in section XIX-D of this ordinance entitled "Water Resource Protection District, City of Newburyport". The watershed zones are described as follows:

Watershed Zones:

a. Zone A: (a) The land area between the surface water source and the upper boundary of the bank; (b) the land area within a 400 foot lateral distance from the upper boundary of the bank of a Class A surface water source, as defined in 314 CMR 4.05 (3)(a); and (c) the land area within a two hundred-foot lateral distance from the upper boundary of the bank of a tributary or associated surface water body.
b. Zone B: The land area within one-half mile of the upper boundary of the bank of a Class A surface water source, as defined in 314 CMR 4.05(3)(a), or edge of the watershed, whichever is less. However, Zone B shall always include the land area within a four-hundred-foot lateral distance from the upper boundary of the bank of the Class A surface water source.
c. Zone C: The land area not designated as Zone A or Zone B within the watershed of a Class A water source as defined in 314 CMR 4.05(3)(a).
d. Zone I: The zone encompassing the area which falls within a four-hundred-foot radius from the municipal well shaft.
e. Zone II: The area of an aquifer which contributes water to a municipal well under the most severe pumping and recharge conditions that can be realistically anticipated (one hundred eighty (180) days of pumping at safe yield with no recharge from precipitation), as defined in 310 Code of Massachusetts Regulations (CMR) 22.00.

(Ord. of 7-27-98(5); Ord. of 10-27-03)

XIX-D - Establishment and delineation of a water resource protection district.

This ordinance establishes within the City of Newburyport certain water resource protection zones, consisting of watershed areas of the Indian Hill Reservoir, Artichoke Reservoir, Bartlett Spring Pond and Zone I and Zone II of the groundwater sources, which are delineated on a map. This map is at a scale of one inch to eight hundred (800) feet and is entitled "Water Resource Protection District, City of Newburyport" dated February 25, 2003. This map is hereby made part of the city zoning ordinance and is on file in the office of the city planner and water department office.

(Ord. of 7-27-98(5); Ord. of 10-27-03)

XIX-E - Allowed uses within the water resource protection district.

Water supply related activities will not be subject to regulations within this ordinance [section].

The following uses are allowed within the water resource protection district, provided that all necessary permits, orders, or approvals required by local, state or federal law are first obtained:

1. Conservation of soil, water, plants, and wildlife.
2. Outdoor recreation, nature study, boating, fishing, and hunting where legally permitted, subject to sections XIX-H, I, and J (prohibited uses) and section XIX-K (special permitted uses).
3. Foot and/or bicycle paths and associated bridges.
4. Normal operation and maintenance of existing water bodies and dams, splash boards, and other water control, supply, and conservation devices.
5. Maintenance, repairs, and enlargement of any existing structure, subject to sections XIX-H, I, and J (prohibited uses) and section XIX-K (special permitted uses).
6. Residential development, subject to sections XIX-H, I, and J (prohibited uses) and section XIX-K (special permitted uses).
7. Farming, gardening, nursery, conservation, harvesting, and grazing, subject to sections XIX-H, I, and J (prohibited uses) and section XIX-K (special permitted uses).
8. Construction, maintenance, repair, and enlargement of drinking water supply related facilities such as, but not limited to, wells, pipelines, aqueducts, and tunnels. Underground storage tanks related to these activities are not categorically allowed.

(Ord. of 7-27-98(5))

XIX-F - Prohibited uses within the water resource protection district.

Notwithstanding the general power conferred by section X-H(6)(A) of the zoning ordinance upon the planning board to grant use variances, no use variance shall be granted so as to permit any of the uses prohibited by the foregoing section.

The following uses are prohibited within the entire water resource protection district:

1. Landfills and open dumps as defined in 310 CMR 19.006.
2. Landfilling of sludge or septage as defined in 310 CMR 32.05.
3. Storage of sludge and septage, unless such storage is in compliance with 310 CMR 32.30 and 310 CMR 32.31.

4. Automobile graveyards and junkyards, as defined in M.G.L.A. c. 140B, § 1.
5. Storage of liquid hazardous materials, as defined in M.G.L.A. c. 21E, unless in a freestanding containers within a building or above ground with secondary containment adequate to contain a spill one hundred ten (110) percent the size of the containers total storage capacity.
6. Stockpiling and disposal of snow and ice containing deicing chemicals as well as disposal of such material directly into a tributary to the principal water supply.
7. Structures other than those related to flood control or water supply, within the Zone A or Zone I.
8. Placement of fill, unless the fill has been designated as "clean fill."
9. Storage of deicing chemicals, unless such storage (including loading areas) is within a structure designed to prevent the generation and escape of contaminated runoff or leachate.
10. Any other activity deemed likely to cause or contribute to the contamination of the public water supply.
11. No water shall be diverted out the water resource protection district.

(Ord. of 7-27-98(5); Ord. of 10-27-03)

XIX-G - Prohibited uses within the Zone A, Zone B, Zone I and Zone II.

In addition to prohibitions in section XIX-H, the following uses are prohibited within the Zone A, Zone B, Zone I, and Zone II of the water resource protection district:

1. Individual sewage disposal systems that are designed and located in accordance with 310 CMR 15.000 to receive more than one hundred ten (110) gallons of sewage per quarter acre under one ownership per day, or four hundred forty (440) gallons of sewage on any acre under one ownership per day, whichever is greater, except the replacement or repair of an existing system that will not result in design capacity above the original design.
2. Storage of animal manure unless covered or contained so as to prevent the generation and escape of contaminated runoff or leachate.
3. Earth removal, consisting of the removal of soil, loam, sand, gravel or any other earth material (including mining activities) to within six (6) feet of historical high groundwater as determined from monitoring wells and historical water table fluctuation data compiled by the United States Geological Survey, except for excavations for building foundations, roads, or utility works.
4. Facilities that generate, treat, store, or dispose of hazardous waste subject to M.G.L.A. c. 21C and 310 CMR 30.00, except the following:
    a. Waste oil retention facilities required by M.G.L.A. c. 21C, § 52A.
    b. Water remediation treatment works approved under 314 CMR 5.00.
5. Treatment works that are subject to 314 CMR 5.00, including privately owned sewage treatment facilities, except the following:
    a. Replacement or repair of an existing treatment works that will not result in a design capacity greater than the design capacity of the existing treatment works.
    b. Replacement of existing subsurface sewage disposal system(s) with waste treatment works that will not result in a design capacity greater than the design capacity of the existing sewage disposal system(s).

   c. Treatment works designed for the treatment of contaminated surface water and groundwater, approvec Massachusetts Department of Environmental Protection.

6. Industrial and commercial uses which discharge process wastewater on site.
7. Alteration of any bordering vegetated wetland.
8. Incinerators.
9. Storage of liquid petroleum products, except the following:
   a. Normal household use, outdoor maintenance, and heating of a structure.
   b. Waste oil retention facilities required by statute, rule, or regulation.
   c. Emergency generators required by state regulations.
   d. Treatment works approved under 314 CMR 5.00 for treatment of ground or surface waters.

   Provided that such storage, listed in items a. through d. above, is in freestanding containers within buildings or above ground with secondary containment adequate to contain a spill the size of one hundred ten (110) percent [of] the container's total storage capacity.
10. Commercial repair, servicing, washing, and rebuilding of vehicles, boats, and other large motorized equipment other than for normal household or farming activities.
11. Storage of commercial fertilizers, as defined in M.G.L.A. c. 128, § 64, unless such storage is within a structure designed to prevent the generation and escape of contaminated runoff or leachate.

(Ord. of 7-27-98(5))

XIX-H - Prohibited uses within the Zone A and Zone I.

In addition to the prohibitions and restrictions in sections XIX-H and I of this water resource protection district, the following activities are prohibited within the Zone A and Zone I, but are not limited to this list.

1. Any activity, other than for flood control or municipal water supply, which causes earth movement or disturbance.
2. Construction or placement of any permanent structures, other than those associated with flood control or water supply.
3. Any surface or subsurface discharge, including, but not limited to, stormwater or hazardous materials, except as allowed by special permit.
4. Wading, swimming, bathing or boating in the municipal water supply or its tributaries.
5. Horse paths.
6. Construction of new roads.
7. Any burial place or cemetery within one hundred (100) feet of the high water mark of a tributary.
8. Storage of animal manure, even if covered and contained.
9. Facilities that generate, treat, store, or dispose of hazardous waste subject to M.G.L.A. c. 21C and 310 CMR 30.00, regardless of size and quantity of hazardous waste generated.
10. Snowmobiling, dirt biking, all terrain vehicles (ATVs), sea planes and any other activities that in the opinion of the SPGA presents a threat to the water supply or the watershed.

(Ord. of 7-27-98(5))

XIX-I - Uses requiring a special permit within the entire water resource protection district.

The following uses and activities are allowed only upon the issuance of a special permit by the planning board under such conditions as the board may require.

1. Enlargement or alterations of existing uses that do not conform to the water resource protection district.
2. Application of pesticides, herbicides, insecticides, fungicides, and rodenticides for nondomestic or nonagricultural uses in accordance with the state and federal standards. The special permit shall be granted if such standards are met. If applicable, the application shall provide documentation of compliance with a yearly operating plan (YOP) for vegetation management operations under 333 CMR 11.00 or a Department of Food and Agriculture approved Pesticide Management Plan or Integrated Pest Management (IPM) program under 333 CMR 12.00.
3. Application of fertilizers for nondomestic or nonagriculture uses. Such application shall be made in a manner so as to minimize adverse impacts to surface water and groundwater quality due to nutrient transport, deposition, and sedimentation.
4. Activities which involve the handling of toxic or hazardous materials in quantities greater than those associated with normal household use, if allowed in the underlying zoning (except as prohibited under sections XIX-H, I, and J). Such activities shall require a special permit to prevent contamination of surface water and groundwater.
5. Construction of dams or other control devices, ponds or other changes in water bodies or courses, created for swimming, fishing or other recreational uses, agricultural uses, or drainage improvements. Such activities shall not adversely affect water quality or quantity.
6. Any use that will render impervious more than five thousand (5,000) square feet of a residential lot or ten thousand (10,000) square feet of a nonresidential lot. A system for groundwater recharge shall be provided which does not degrade ground or surface water quality. For all nonresidential uses, recharge shall be by storm water infiltration basins or similar systems covered with natural vegetation. Dry wells shall be used only where other methods are infeasible. For all nonresidential uses, all such infiltration basins and dry wells shall be preceded by oil, grease, and/or sediment traps to facilitate removal of contaminants. All recharge areas shall be regularly maintained in proper working order by the owner.
7. Residential construction upon a lot with an average slope exceeding fifteen (15) percent. An acceptable plan for site stabilization and control of erosion and sedimentation shall be provided.
8. Any new stormwater runoff shall be set back from the receiving water a minimum of one hundred (100) feet, and shall include best management practices appropriate to the site. Existing and replacement discharges shall be set back from the receiving water when either the site stormwater drainage system is changed or the discharge is increased. The best management practices shall be designed so as to maximize infiltration and minimize erosion, and to mitigate water quality impacts, including those due to total suspended solids and oil and grease. This applies to stormwater runoff from all impervious surfaces, including roads and parking lots.

(Ord. of 7-27-98(5); Ord. of 10-27-03)

XIX-J - Procedures for issuance of special permit.

1. The special permit granting authority (SPGA) under this ordinance shall be the planning board. Such special

permit may be granted if the SPGA determines, in conjunction with the board of water commission, sewer commission, board of health, conservation commission and department of public works that the intent of this ordinance, as well as its specific criteria, are met. The SPGA shall not grant a special permit under this section unless the petitioner's application materials include, in the SPGA's opinion, sufficiently detailed, definite, and credible information to support positive findings in relation to the standards given in this section. The SPGA shall document the basis for any departures from the recommendations of the other municipal boards or agencies in its decision.

2. Upon receipt of the special permit application and filing fee, the SPGA shall transmit one copy each to the board of water commission, sewer commission, board of health, conservation commission and the department of public works for their written recommendations. Failure to respond in writing within sixty (60) days of receipt shall indicate approval or no desire to comment by said agency. The requisite number of application copies shall be furnished by the applicant.
3. The SPGA may grant the required special permit only upon finding that the proposed use meets the requirements specified in sections XIX-E, F, G, H, and I of this ordinance, any regulations or guidelines adopted by the SPGA, and the following standards. The proposed use must:
   a. In no way adversely affect the existing or potential quality or quantity of water that is available for on-site recharge in the water resource protection district, during or after construction.
   b. Be designed to avoid substantial disturbance of the soils, topography, drainage, vegetation, and other water related natural characteristics of the site to be developed, in adherence to the practices outlined in "Guidelines for Soil and Water Conservation in Urbanizing Areas of Massachusetts" (USDA Soil Conservation Services, October 1977).
4. The SPGA may adopt regulations to govern design features of projects. Such regulations shall be consistent with subdivision regulations adopted by the city.
5. The applicant for a special permit shall file fifteen (15) copies of a site plan and attachments. The site plan shall be drawn at a proper scale and be stamped by a professional engineer as determined by the SPGA. All additional submittals shall be prepared by qualified professionals. The site plan and its attachments shall include at a minimum the following information where pertinent:
   a. A complete list of chemicals, pesticides, fertilizers, fuels, and other potentially hazardous materials to be used or stored on the premises in quantities greater than those associated with normal household use.
   b. For those activities using or storing such hazardous materials, a hazardous materials management plan shall be prepared and filed with the hazardous materials coordinator, fire chief, and board of health. The plan shall include:
      i. Provisions to protect against the discharge of hazardous materials or waste to the environment due to spillage, accidental damage, corrosion, leakage, or vandalism, including spill containment and clean-up procedures.
      ii. Provisions for indoor secured storage of hazardous materials and waste on impervious floor surfaces.
      iii. Evidence of compliance with Regulations of the Massachusetts Hazardous Waste Management Act 310 CMR 30.00, including obtaining an EPA identification number from the Massachusetts Department of Environmental Protection.
   c. Proposed down-gradient locations for surface water or groundwater monitoring should the SPGA deem the activity a potential surface water or groundwater threat.

6. The SPGA shall hold a public hearing, in conformity with the provision of M.G.L.A. c. 40A, § 9, within ninety (90) d after the filing of the application and after the review by the appropriate city boards, departments, and commis

Notice of the public hearing shall be given by publication and posting and by first-class mailing to "parties of interest" as defined in M.G.L.A. c. 40A, § 11. The decision of the SPGA and any extension, modification, or renewal thereof shall be filed with the SPGA and city clerk within ninety (90) days following the closing of the public hearing. Failure of the SPGA to act within ninety (90) days shall be deemed as a granting of the permit. However, no work shall commence until a certification is recorded as required by said M.G.L.A. c. 40A, § 11.

(Ord. of 7-27-98(5); Ord. of 10-27-03)

XIX-K - Enforcement.

Written notice of any violation of this ordinance [section] shall be given by the building inspector/code enforcement officer to the responsible person as soon as possible upon observation, detection, knowledge or proof that a violation has occurred. Notice to the assessed owner of the property shall be deemed notice to the responsible person. Such notice shall specify the requirements or restriction violated and the nature of the violation, and may also identify the actions to remove or remedy the violations, preventive measures required for avoiding future violations, and a schedule of compliance. A copy of such notice shall be submitted to the board of water commission, sewer commission, building inspector, board of health, conservation commission and department of public works. The cost of containment, cleanup, or other action of compliance shall be borne by the assessed owner of the property.

For situations that require remedial action to prevent impact to the water resources within the water resource protection district, the building inspector, the board of health, or any of their agents may order the owner and/or operator of the premises to remedy the violations. If said owner and/or operator does not comply with said order, the building inspector, the board of health, or any of their agents, if authorized to enter upon such premises under the terms of the special permit or otherwise, may act to remedy the violation. The cost of remediation shall be the sole responsibility of the owner and/or operator of the premises.

(Ord. of 7-27-98(5))

XIX-L - Severability.

A determination that any portion or provision of this water resource protection district ordinance is invalid shall not invalidate any other portion or provision thereof, nor shall it invalidate any special permit issued previously thereunder.

(Ord. of 7-27-98(5))

APPENDIX D

Memorandum

To: Tom Cusick

From: Don Kretchmer CLM and Ken Wagner PhD CLM

Re: Water quality summary and discussion of 2020 cyanobacteria blooms.

Date: October 26, 2020

Overview and Background

DK Water Resource Consulting LLC was contracted to provide monitoring assistance for the four Newburyport Reservoirs. This evaluation included a brief review of historical information and several field visits from September 5, 2019 through September 9, 2020. It also includes discussion of data collected by Newburyport personnel during the summer and fall of 2020. Data collected included field data, typical limnological analyses focused on nutrients and phytoplankton and analyses to characterize the August 2020 cyanobacterial bloom in Upper and Lower Artichoke Reservoirs and the October 2020 bloom in Indian Hill Reservoir. WRS assisted in the evaluation of the cyanobacteria blooms

The four Newburyport Reservoirs include three in series reservoirs and one stand-alone reservoir (Figure 1). Indian Hill Reservoir drains to Upper Artichoke which then drains to Lower Artichoke. The Newburyport water treatment plant draws water from Lower Artichoke. Bartlett Pond is a smaller reservoir near the water treatment plant and the Merrimack River. Only Indian Hill Reservoir has any substantial depth (6M). The other reservoirs are relatively shallow and contain substantial rooted aquatic plant growth. There are numerous small tributaries to the reservoirs, particularly Indian Hill Reservoir and Upper Artichoke Reservoir (Figure 1). Reservoir and watershed areas are presented in Table 1. The larger the watershed relative to the reservoir area, the more difficult it is to manage reservoir water quality through watershed management, particularly in developed watersheds. Both of the Artichoke Reservoirs have large watershed areas relative to their size making them particularly susceptible to excessive nutrient loading and associated algal (cyanobacteria) and plant growth. The history and further characteristics of the reservoirs are summarized in the 2016 reservoir study (AECOM 2016).

Algae (and cyanobacteria) growth in the supply reservoirs fueled by nutrients from the watershed can directly affect total organic carbon (TOC) and suspended solids levels in raw water and processes in the treatment plant. Stormwater runoff from development, erosion, higher water temperatures, longer growing seasons and lower flushing rates due to prolonged droughts have the potential to increase the magnitude and duration of algal (cyanobacteria) growth in the reservoirs now and in the future. In addition to issues related to increased TOC (from algal cells) and the formation of disinfection byproducts, nutrient enrichment can increase the risk for cyanobacteria blooms such as the one documented in Upper Artichoke Reservoir in early August 2020. Many cyanobacteria species can produce toxins, an undesirable situation for a drinking water resource.

The nutrient that most likely fuels algal (cyanobacteria) blooms in the Newburyport Reservoirs is phosphorus. Monitoring data from 2015 and 2019-2020 indicates that there is more than ample phosphorus in the two Artichoke Reservoirs to support blooms like the recent bloom on upper Artichoke. While blooms on Indian Hill and Bartlett are less likely due to lower phosphorus concentrations, they are still possible. Episodic inputs from the watershed can boost phosphorus levels and many cyanobacteria can grow at the sediment-water interface utilizing phosphorus released from sediment without ever causing elevated dissolved phosphorus concentrations in the water above. Managing the reservoirs and watersheds in a manner that reduces the reservoir phosphorus concentrations and anticipates current and future risks is essential. Nutrient concentrations and the reservoir's potential response to these nutrients are discussed further below.

The Newburyport Reservoirs experienced a major cyanobacteria bloom in Upper and Lower Artichoke Reservoirs in August 2020 and a minor bloom in October 2020 in Indian Hill reservoir. The dynamics of these blooms are described after the water quality summary.

Figure 1: Newburyport Water Supply Reservoirs and Monitoring Locations.

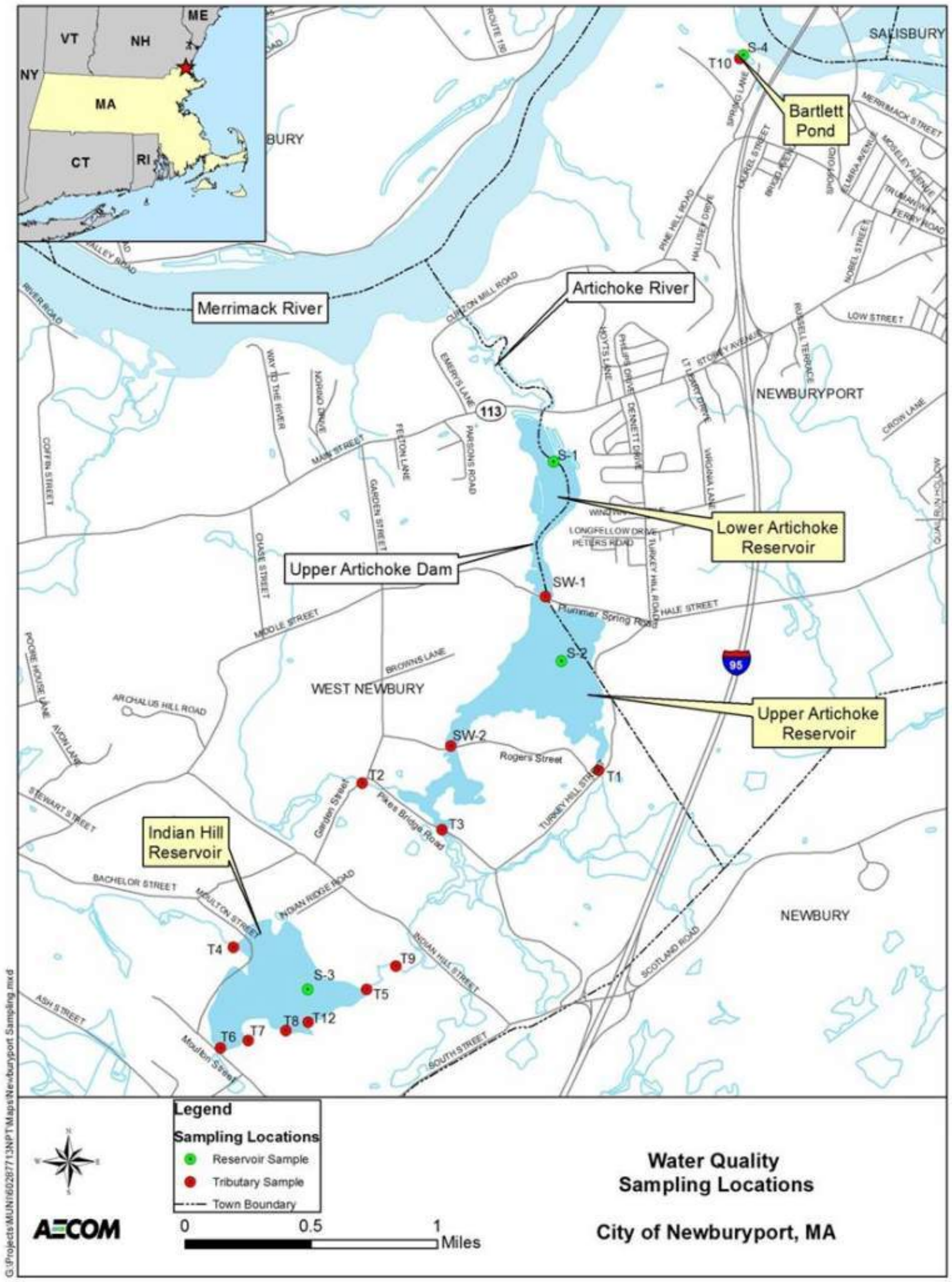


Table 1: Reservoir Characteristics.

Table 1. Reservoir Characteristics

Water Supply	Watershed Location	Reservoir Area (ha)	Watershed Area (ha)	Watershed to Reservoir Ratio
Bartlett Pond	Newburyport	0.8	31	39:1
Lower Artichoke Reservoir	Newburyport and West Newbury	15	1,465	95:1
Upper Artichoke Reservoir	Newburyport and West Newbury (southeast corner of watershed extends into Newbury)	49	1,399	29:1
Indian Hill Reservoir	West Newbury	53	191	4:1

2019 and 2020 water quality data

Reservoirs

On September 5, 2019, June 1, 2020, and September 9, 2020 all four reservoirs were sampled to provide a comparison to historic data as well as future data. In-reservoir samples were analyzed for the following parameters and laboratory standard operating procedures for each parameter were included in the Quality Assurance Project Plan (QAPP) for the 2016 watershed study (AECOM 2016). Parameters evaluated included:

- Total Phosphorus (TP),
- Soluble Reactive Phosphorus,
- Nitrate as Nitrogen,
- Ammonia as Nitrogen,
- Total Kjeldahl Nitrogen (TKN),
- Dissolved Manganese (Mn),
- Dissolved Iron (Fe),
- Total Alkalinity, and
- Total Suspended Solids (TSS).

Soluble reactive phosphorus was not analyzed from June 2020 or September 9, 2020 samples due to lab constraints related to the Covid-19 pandemic. Chlorophyll *a* was analyzed from the epilimnetic/whole water column core sample (which represents the extent of the photic zone) collected at each reservoir unless water depth precluded collection of a core. In those instances, samples were collected at a depth of 0.5m. Secchi transparency, pH, specific conductance, temperature and dissolved oxygen were measured in the field. All water quality results from 2019 and 2020 are presented in Attachment A.

Phosphorus is the primary limiting nutrient in most northern temperate lakes, hence algal growth is typically directly related to phosphorus concentrations. The 2019 and 2020 total phosphorus concentrations in Lower Artichoke reservoir were similar to that observed in 2015 while 2019 and 2020 results for Upper Artichoke were near the upper range observed in 2015. Indian Hill total phosphorus concentrations in 2019 and early 2020 were similar to that observed in 2015 but September 2020 results were the highest observed to date. Concentrations of phosphorus in Bartlett in 2019 and 2020 were roughly half that observed in 2015. Total phosphorus results from the AECOM (2016) study and the recent (2019-2020) monitoring are presented in Table 2.

Table 2. Summary of Total Phosphorus Results for the Newburyport Reservoir System, April to October 2015, September 5, 2019, June 1, 2020 and September 9, 2020.

	2015 results			9/5/2019	6/1/2020	9/9/2020
Sampling Location	Average (µg/l)	Maximum (µg/l)	Minimum (µg/l)	(µg/l)	(µg/l)	(µg/l)
Lower Artichoke (S-1)	23.0	29.0	11.7	24.6	21.7	18.6
Upper Artichoke (S-2)	34.4	45.1	16.1	42.0	37.4	43.2
Indian Hill (epilimnion; April to October) (S-3)	13.8	17.5	8.9	13.5	16.6	18.2
Bartlett Pond (S-4)	25.2	40.1	17.7	13.3	12.6	11.8

Based on 2019 and 2020 phosphorus concentrations, Indian Hill and Bartlett would be classified as mesotrophic or moderately productive while both Upper and Lower Artichoke would be classified as eutrophic or highly productive. The productivity of a lake or reservoir is an indication of the amount of plant or algal (cyanobacteria) growth that can be supported with the available nutrients (in this discussion, phosphorus). All 4 reservoirs exhibit high phosphorus concentrations at times however, and both Upper Artichoke (throughout 2019 and 2020) and Indian Hill (in 2020) total phosphorus concentrations were elevated relative to 2015. This significantly increases the likelihood of algal and cyanobacteria blooms. Algal (cyanobacteria) growth is of concern to water utilities due to the potential for disinfection byproducts, taste and odor compounds, and cyanobacterial toxins.

Chlorophyll *a* is the photosynthetic pigment found in all species of freshwater algae and cyanobacteria. It is not found at the same ratio to biomass or other pigments in all algae groups, with cyanobacteria tending to have rather low chlorophyll *a* relative to total biomass or other pigments. The concentration of chlorophyll *a* observed in Upper Artichoke and Indian Hill reservoirs in 2019 was similar to that observed in 2015. Lower Artichoke showed a chlorophyll a concentration in 2019 near the maximum seen in 2015 while concentrations in Bartlett in 2019 were roughly 1/3 those observed in 2015. Based on the 2019 results, Lower Artichoke is increasing in productivity while Bartlett is decreasing. The June 2020 samples showed chlorophyll *a* concentrations that were low in all four reservoirs. The low concentrations observed are likely due to the time of year the sampling occurred, early in the growing season when lower temperatures slow growth. Sufficient nutrients appear to be available to support substantial algal (cyanobacteria) growth most of the time. Chlorophyll *a* concentrations in all 4 reservoirs were higher in September 2020 than earlier in the year, a typical pattern in this region. Upper Artichoke concentrations were the highest recorded and likely related to the August 2020 bloom.

Table 3. Summary of Chlorophyll-a Results for the Newburyport Reservoir System, April to October 2015, September 5, 2019, June 1, 2020 and September 9, 2020.

	2015 results			9/5/2019	6/1/2020	9/9/2020
Sampling Location	Average (µg/l)	Maximum (µg/l)	Minimum (µg/l)	(µg/l)	(µg/l)	(µg/l)
Lower Artichoke (S-1)	7.0	14.1	1.9	12.6	1.3	2.9
Upper Artichoke (S-2)	7.7	12.2	1.6	7.0	2.9	18.3
Indian Hill (S-3a)	7.7	12.4	1.9	5.0	1.4	6.1
Bartlett Pond (S-4a)	10.9	22.5	2.3	3.2	4.8	5.3

Temperature and dissolved oxygen profiles conducted in 2019 at the deepest spot in each reservoir indicate that none of the reservoirs were stratified at the time of sampling. In June 2020, only Indian Hill was stratified and only weakly. Temperatures varied a few degrees by depth throughout the water column; however, dissolved oxygen was relatively consistent and adequate throughout the water column. In September of 2020 there was no stratification in any of the reservoirs but dissolved oxygen depletion was observed near the bottom of Indian Hill. This may have been a factor in the emergence of the cyanobacteria bloom in mid-October.

Specific conductance is a measure of the total amount of dissolved substances (salts and other ions) in water. Specific conductance values (Attachment A) were moderate and relatively consistent from the surface to the bottom. The highest specific conductance values were observed in Bartlett Pond, closest to the tidal section of the Merrimack River.

pH is a measure of the acidity of water. Neutral pH is 7 while pH values below 7 are acidic and values over 7 are alkaline. The pH of all the reservoirs except Bartlett was above 7.0 in September of 2019 and September of 2020, consistent with moderate to high levels of algal photosynthesis (productivity) which tends to increase the pH as the cells use carbon dioxide in the water for photosynthesis. In June 2020, the observed pH was somewhat lower consistent with lower levels of algal photosynthesis.

Nitrogen was monitored in 2019 and 2020 to give an indication of whether phosphorus or nitrogen availability had the potential to limit algal growth. Data from all four reservoirs showed that phosphorus was in shorter supply than nitrogen suggesting that phosphorus concentrations are likely dictating the amount of algal growth observed. However, a low ratio of nitrate nitrogen to phosphorus tends to favor species of cyanobacteria that have specialized cells that allow these algae to utilize atmospheric nitrogen dissolved in the water. Low nitrates were observed in the reservoirs. So, while phosphorus is expected to control algae abundance, nitrogen forms will affect which algae become abundant and favor cyanobacteria in these reservoirs at least during later summer.

Iron and manganese were also evaluated in reservoir samples. Concentrations in all reservoirs were below USEPA Secondary Maximum Contaminant Level standards (SMCL) for drinking water (0.3 mg/l for iron and 0.05 mg/l for manganese) in September 2019 but slightly above the standards for iron in Upper Artichoke and manganese in Indian Hill in June 2020. If low oxygen was a consistent problem in the reservoirs, we would expect elevated iron and manganese concentrations. Oxygen may indeed be low in surficial sediment, allowing release of iron, manganese and phosphorus, but adequate oxygen just above the sediment and through most of the water column in most areas on most dates will cause these elements to precipitate back out. The ability of some algae, notably many species of cyanobacteria, to grow at the sediment-water interface using nutrients released from sediment before they encounter oxygen and are inactivated is a likely cause of the observed blooms. Those cyanobacteria form gas pockets in cells and float upward after enough nutrients have been absorbed. This happens somewhat synchronously, resulting in rapidly forming blooms and seemingly consistent with observations in the Newburyport reservoirs.

Tributaries

Selected tributaries were monitored on July 7, 2020, July 23, 2020, September 11,2020, October 17, 2020 and October 19, 2020. High concentrations of phosphorus were observed at Station T12 (tributary to Indian Hill) on July 7, 2020 and October 17, 2020. and at T2 (tributary to Upper Artichoke) on 7/23/2020. During the 2015 study (AECOM 2016), extremely high phosphorus concentrations were observed at stations T7 and T8 (tributaries to Indian Hill). These two stations (and several others) were not sampled during 2020 presumably due to lack of flow. The dry period we are currently experiencing greatly reduced streamflow regionally and many intermittent reservoir tributary streams were dry through the period which encompassed the cyanobacteria bloom. Because nutrient inputs to the reservoirs from these small tributaries can greatly influence reservoir water quality, it is recommended that these tributaries be regularly monitored during both dry periods and wet weather. It is especially critical to collect samples during the spring and summer when these nutrient inputs are potentially available to fuel summer algal (cyanobacteria) blooms. Some of the incoming phosphorus may be readily available while some of the load may be particulate and will settle to the bottom where it can become part of the sediment base that supports algae growing at that interface. It is quite likely that patterns of elevated concentrations will emerge in certain tributaries that will set the stage for upstream investigation and remedial action. Whether the immediate source of nutrients is the sediment or the tributaries, the original source was almost certainly the watershed, and dominant sources will need to be controlled to improve water quality in the reservoirs over the longer term.

Historic Sediment Analysis

Sediment quality sampling was conducted in the Artichoke Reservoir System and Bartlett Pond on May 21, 2015 (AECOM 2016) to identify the nutrient status of the reservoir sediments as well as the potential for the sediment phosphorus to be released to the water column. The sediment sampling event targeted the upper 3.5 to 4 inches of sediment which are typically the sediments that interact with the water column. Samples were collected using an Eckman dredge. Three to four sediment samples within deeper areas at each reservoir were composited into one sample per reservoir. The FSP, including details regarding sediment sampling, and SOPs for laboratory analysis are included as appendices to the QAPP (Attachment B). Sediment samples were analyzed for the following parameters:

- Total phosphorus
- Loosely bound phosphorus
- Iron bound phosphorus
- Total iron
- Total aluminum
- Total solids
- Grain size analysis

Table 4 includes results of sediment sampling. These data are presented to inform current water quality discussions and will be critical to evaluating alternatives to reduce phosphorus concentrations in the reservoirs and reduce the potential for future cyanobacteria blooms. Total, iron-bound, and loosely-bound phosphorus were highest at the Upper Artichoke Reservoir, while total iron, total aluminum, and total solids were lowest at Upper Artichoke Reservoir. Higher water content in the sample at Upper Artichoke Reservoir may be due to the large amount of algae present that compromised sediment collection, but values <10% are not uncommon in loose sediment. Values for available phosphorus (here the iron-bound and loosely bound fractions) in excess of 50 mg/kg may be a concern and values >200 mg/kg are a definite risk for elevated internal loading of phosphorus. In that regard, Bartlett and Indian Hill have acceptable sediment features while Lower Artichoke represents a moderate risk and Upper Artichoke exhibits a high risk for internal phosphorus loading from sediment.

High aluminum concentrations in the sediments tend to keep phosphorus bound to the sediments even under anoxic conditions, which is desirable. Aluminum present at more than three times the iron level has been found to be sufficient to minimize internal loading. For the sampled reservoirs, however, iron is much more abundant that aluminum. In such cases, high oxygen is needed to keep phosphorus bound to iron in the sediment. As noted above, oxygen in the water column is usually not depleted, but oxygen in the surficial sediment is likely low during much of the summer, setting the stage for possible release of phosphorus that can be used by algae growing near the sediment-water interface.

Table 4. Newburyport Reservoir Sediment Sampling Results, May 21, 2015 (AECOM 2016).

Reservoir	Station	Total P (mg/kg)	Iron-Bound P (mg/kg)	Loosely-Bound P (mg/kg)	Total Iron (mg/kg)	Total Al (mg/kg)	Total Solids (%)
Bartlett Pond	S-4	2,000	31	6.2	99,200	12,100	8.27
Lower Artichoke	S-1	1,500	104	7.7	32,300	12,600	11.9
Upper Artichoke	S-2	2,500	216	18	16,700	8,090	5.24
Indian Hill	S-3	1,600	42	3.5	48,200	35,600	25.2

August 2020 Cyanobacteria Bloom (Upper and Lower Artichoke)

The cyanobacteria bloom in the Upper and Lower Artichoke reservoirs was first observed over the weekend of August 8 and 9th and confirmed on August 10, 2020. The bloom was in both Upper and Lower Artichoke Reservoirs and persisted through much of August. Two water treatments were undertaken with copper sulfate to reduce the biomass of cyanobacteria before they reached the water utility intakes. One half the area of Lower Artichoke was treated with copper sulfate by SOLitude Lake Management on August 19, 2020 and again on August 26, 2020. On August 26, one half of the area of Upper Artichoke was also treated. By August 27, the bloom was visibly much reduced and was essentially gone by September first.

The bloom was confirmed as dominated by *Dolichospermum crassum* (formerly called Anabaena) a type of filamentous cyanobacterium, which constituted most of the cell count and biomass in each sample collected on August 14, 2020, even at the intake. The biomass and cell counts associated with the bloom are presented in Figures 2 and 3 below. The bloom was actively monitored after discovery through a combination of visual observation, microscopic identification and enumeration, field fluorescence, nutrient assessment, and toxicity testing. A variety of individuals and groups worked cooperatively to characterize and ultimately treat the bloom. The bloom response team and their primary roles are summarized in Table 5.

Table 5. Organizations involved in 2020 Newburyport Reservoirs bloom response.

Organization	Primary Role
City of Newburyport	Guidance and Public Outreach
Water Treatment Plant Staff	Visual monitoring, plant operations, water quality monitoring, logistics
DK Water Resource Consulting, LLC (DK)	Water quality lead, monitoring
Water Resource Services, Inc. (WRS)	Organism identification and counts, in-reservoir treatability, water quality monitoring
Tighe and Bond Engineers	Long term mitigation of watershed nutrients
AECOM	In-plant treatment options
USEPA	Organism species confirmation
Green Water Labs	Toxicity testing
University of New Hampshire	Phosphorus and chlorophyll *a* analysis
Alpha Labs	Nutrient and metals testing
South Central Connecticut Regional Water Authority	Taste and odor compound analysis
SOLitude Lake Management	Reservoir treatment
Massachusetts DEP	Regulatory guidance and toxicity testing

Visual observation of the progression of the bloom was conducted each day both from shore and through use of a drone operated by the city staff. These observations by Newburyport city and water plant staff helped all members of the response team locate the bloom and develop both sampling and response actions. Visual observations were coupled with field fluorometric measurements of phycocyanin which are strongly correlated with the density of cyanobacteria. Results of these analyses are shown in Figures 2 and 3 below. They show the dynamics of the bloom over time in both Upper and Lower Artichoke Reservoirs.

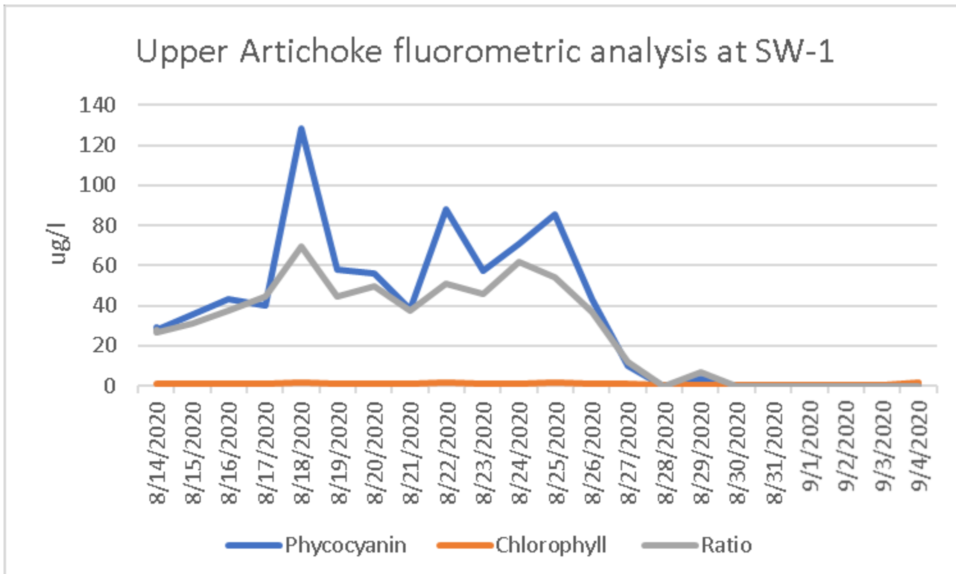


Figure 2. Fluorescence at SW-1 near the lower end of Upper Artichoke Reservoir

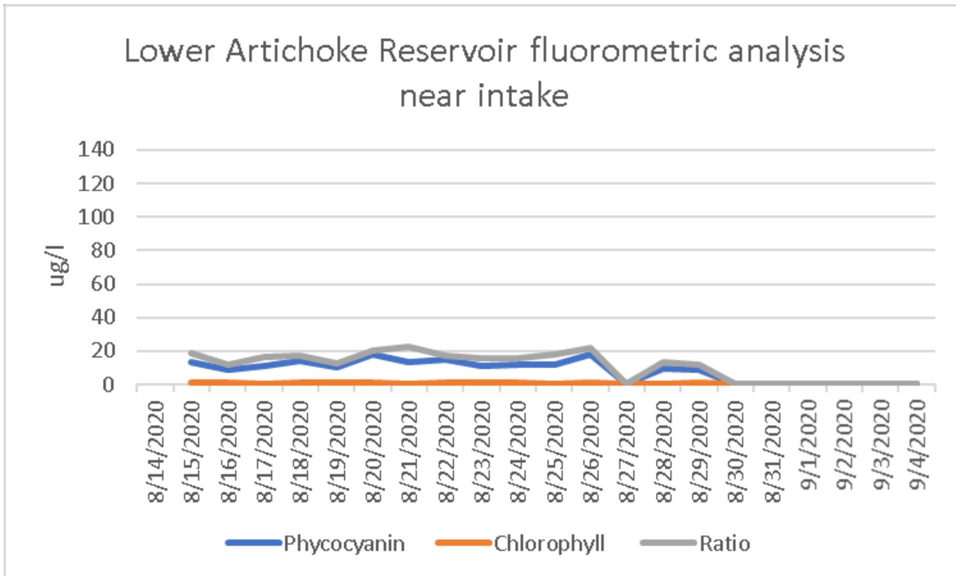


Figure 3. Fluorescence near the water intake in the lower end of Lower Artichoke Reservoir.

Initial identification of the dominant organism in the bloom as *Dolichospermum crassum* was completed by USEPA . The first full quantification of the phytoplankton community including species, cell counts and biomass estimates was conducted on August 14 by WRS. Subsequently, WRS analyzed samples collected on August 14, 19, 24, 27 and September 2. Results of those assessments are summarized in Figures 4 and 5. Full taxonomic data are provided in Attachment B.

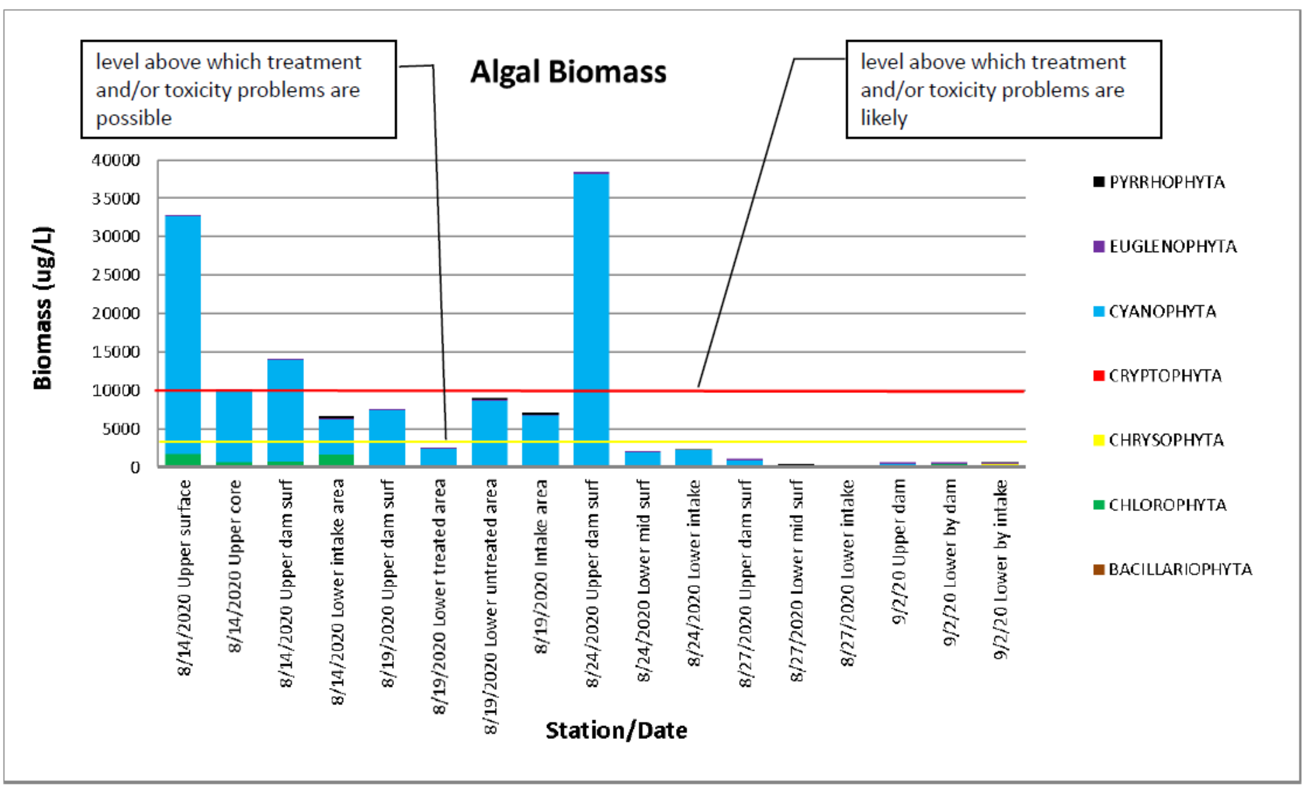


Figure 4. Algal Biomass in Artichoke Reservoirs in August and early September 2020.

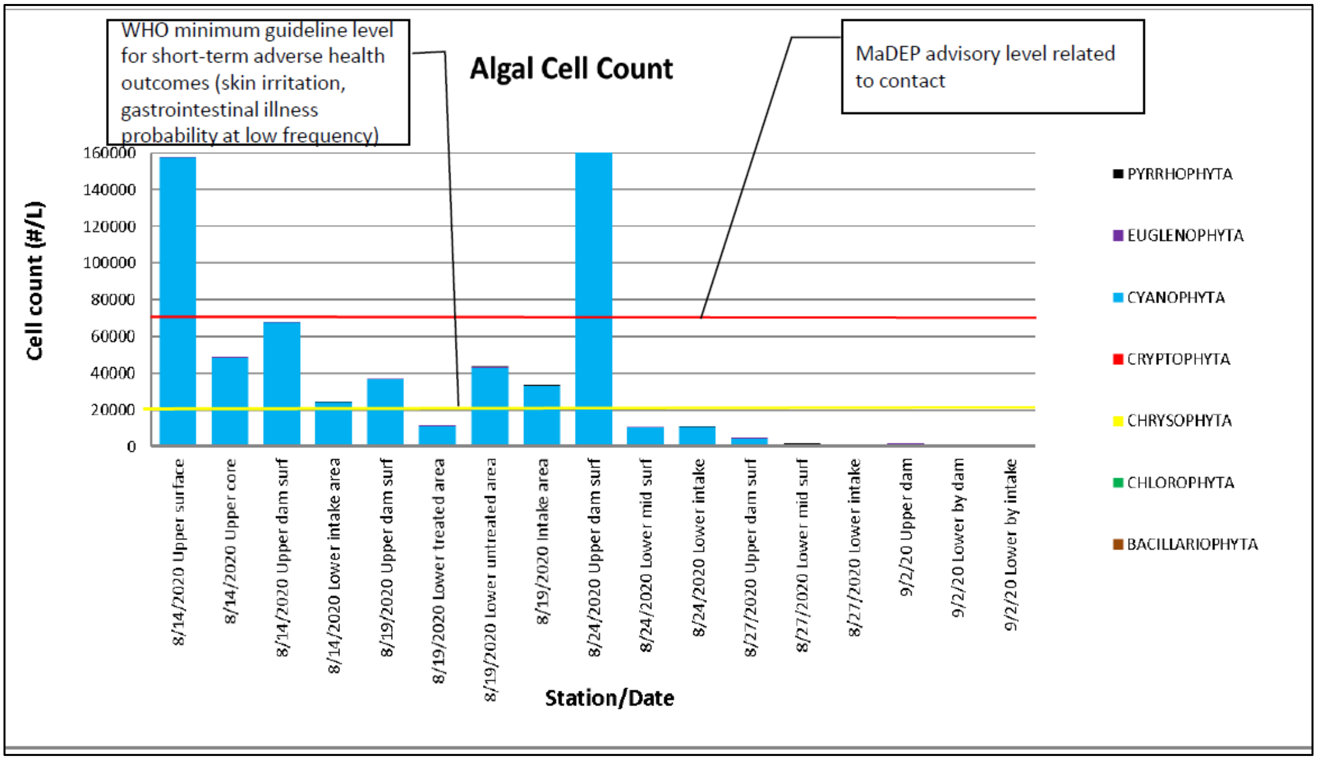


Figure 5. Algal Cell Counts in Artichoke Reservoirs in August and early September 2020.

The figures illustrate that both biomass and cell counts were above thresholds where toxicity concerns were possible and treatment challenges might be anticipated. The algal community was dominated by cyanobacteria throughout the period encompassed by the bloom. Initial observations after the first samples were analyzed suggested the following:

1. The dominant cyanobacterium was *Dolichospermum crassum*, a taxon that is associated with toxic events, but the probability of toxin production is not high (about 1 in 5). Liver and nerve toxins could be produced, however, so possible toxicity was a concern. Two other possible toxin producing cyanobacteria were also found, *Dolichospermum planktonicum* and *Cuspidothrix issatchenkoi*, but neither was abundant. Other algae present represented no health threat.
2. Most filaments of *Dolichospermum crassum* were shorter than usual and had both heterocytes (where nitrogen gas is fixed and gives these algae an advantage over other algae that cannot utilize dissolve N_2 gas) and akinetes (resting stages produced like seeds in higher plants) suggesting that the cyanobacteria may not have been healthy and the bloom may have declined within a week or two without intervention. However, due to uncertainty, it was still deemed worthwhile to treat the existing bloom to minimize current and longer-term impacts.
3. The concentration in the surface grab sample from the upper reservoir was higher than the 70,000 cells/mL that the Commonwealth of Massachusetts uses as a threshold of concern for release of

toxin from dying cells when a treatment is performed. However, the quantity of cells/mL in the core sample (composite from 0-2 m) at the same upper reservoir station was below the threshold at slightly <50,000/mL; these cyanobacteria are buoyant and congregate at the surface, so on average at the upper reservoir station the concentration was high but not excessive.

4. The concentration in the water passing from the upper to lower reservoir was elevated but slightly below the 70,000 cells/mL threshold at about 67,000 cells/mL. That was deemed too close to the threshold to be sure the value is actually lower due to potential counting error. The concentration of cyanobacteria cells moving from the upper to lower reservoir was deemed to be high enough to warrant concern if toxins were being produced.
5. The concentration in the water at the intake in Lower Artichoke was elevated but low relative to the other stations at about 24,000 cells/mL. However, the drone photos suggested ongoing increases in the concentration of cyanobacteria near the intake.
6. No toxicity was found in tests run at the beginning of the bloom for the raw and finished water, but these samples were collected before a lot of very green upper reservoir water entered the lower reservoir. Additional testing was recommended.
7. Biomass values were high enough in all samples to compromise filter run times.

On August 19, 2020, a copper sulfate treatment was conducted on the upper half of Lower Artichoke Reservoir. Water was still moving from Upper Artichoke to Lower Artichoke via a valved pipe, but flow rates were just high enough to maintain the water level in Lower Artichoke. After the treatment, Upper Artichoke (not treated) was still quite green and the algal clumps were visible. Lower Artichoke was murky but less green, both in and out of the treated area. Particles were less individually visible but could still be seen. There was not a huge visible difference between the treated and untreated parts of Lower Artichoke, but the copper may have moved laterally and may have been affecting a larger area than was directly treated.

In the immediate aftermath of treatment, there was no significant temperature stratification (need at least 3 C ° difference to impede mixing). Dissolved oxygen (DO) was high near the surface and declined to the bottom. Values <2 mg/L for DO were obtained at the bottom at all stations. DO was higher in Upper Artichoke and in the untreated part of Lower Artichoke than in the treated area, but was generally acceptable in all locations except right near the bottom. The water column averages appeared to be less an issue of oxygen sag due to treatment than loss of algal-induced oxygen input. That is, the oxygen where no treatment occurred was at or in excess of the saturation point for DO, while the treatment area still had plenty of oxygen in upper waters. All sites had low DO near the bottom, indicative of oxygen demand from the sediments that is more than diffusion from above can satisfy. There were no observed effects on non-target aquatic organisms or fish.

In terms of the algal/cyanobacteria community and density, Upper Artichoke remained high immediately after the treatment as expected since the treatment was downstream of Upper Artichoke, but all sites showed signs of bloom dissipation and the treated area exhibited a major decline just hours after treatment.

On August 24 cyanobacteria counts in Upper Artichoke were higher than the previous week (200,000+ cells/mL for *Dolichospermum*) and there was a rise in the concentration of *Cuspidothrix* (15,000-20,000 cells/mL) but not considered substantially different than the prior week for Upper Artichoke. There was much less *Dolichospermum* in Lower Artichoke, on the order of 7,000-10,000 cells/mL both mid-lake and near the intake. There was some *Cuspidothrix* present in Lower Artichoke as well. Since initial toxicity screening showed little toxicity, the recommendation was made to treat one half of Upper Artichoke and one half of Lower Artichoke on August 26, 2020.

Conditions improved dramatically by September 2, 2020 following the second treatment, at least in terms of cyanobacteria. Both cell counts and biomass were very low in both reservoirs relative to the beginning of the bloom (Figures 4 and 5). There were a few cyanobacteria present in Upper Artichoke that were non-dominant species previously and the primary problem cyanobacterium, *Dolichospermum crassum*, was absent. No cyanobacteria were detected in Lower Artichoke. The algae present in September were primarily ones that do well in water of high dissolved organic content, consistent with the material released through algaecide treatments.

Toxicity testing for microcystins/nodularium (MCs/NODs), anatoxin a (ATX) and cylindrospermopsin (CYN) throughout the bloom (August 14, 20, 27 and September 2) indicated low levels (Upper Artichoke) or the absence of toxins (Lower Artichoke and raw and finished water) in the Artichoke Reservoirs despite the substantial cyanobacterial bloom. The only toxicity reported above method detection limits was for low levels of MCs/NODs) in Upper Artichoke Reservoir (Figure 6). While these levels were above the health advisory level for bottle fed infants (0.3 ppb), this reservoir is well upstream of the intakes in Lower Artichoke where toxicity was below detection limits on all occasions. In addition, toxicity was never detected in the raw water and in the finished water downstream of the intakes.

The low level of toxicity observed is not unusual; toxin production at a hazardous level only occurs in about 20% of visible bloom cases, but is enough of a threat in a water supply to warrant monitoring and treatment since blooms that are not toxic at a point in time may become toxic and toxic blooms may become non-toxic. The mechanisms for this variability in toxicity are not well understood.

An additional threat to drinking water is the presence of taste and odor compounds and increased organic content that can lead to disinfection byproducts with hazardous properties. Taste and odor compounds were assessed on three occasions during the bloom (Figure 7). While elevated concentrations were observed in Upper Artichoke reservoir, concentrations in the raw water remained low throughout the bloom. There is also common occurrence of a sequence of blooms; as a bloom dies out it releases nutrients and has altered water quality in ways that support other algae that may then achieve bloom proportions, setting up a sequence of blooms that can lead to additional threats of toxicity and/or taste and odor. Action in the reservoir and in watershed are advised to minimize future problems.

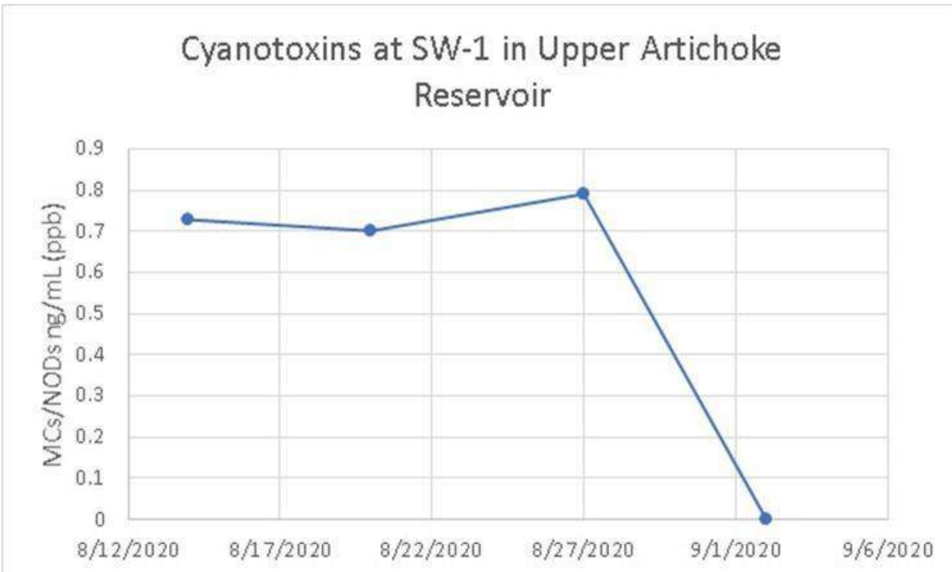


Figure 6. Toxicity results in Upper Artichoke Reservoir in August and early September 2020.

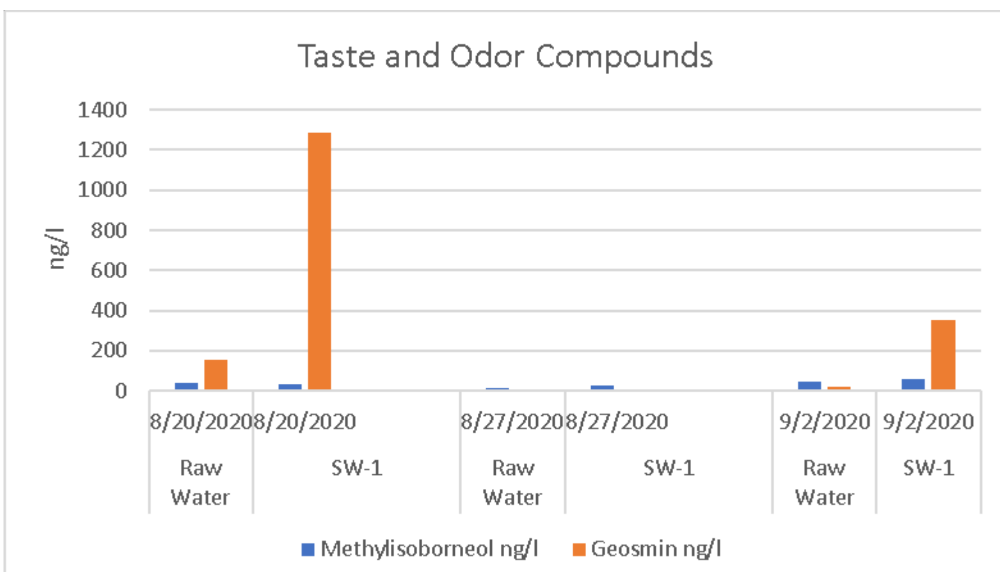


Figure 7. Taste and Odor Compounds in Newburyport Reservoirs in August and early September 2020.

As described above, the nutrient environment in Upper and Lower Artichoke Reservoirs was extremely favorable for a bloom to occur. Nutrient concentrations at the start of the bloom are summarized in Table 6. While both phosphorus and nitrogen play a role in genesis of a bloom, phosphorus is most often the controlling factor. Concentrations of phosphorus in Upper and Lower Artichoke reservoirs on 8/14 were two to four times the concentration that would be desired to substantially reduce the likelihood of blooms in the reservoirs. Reduction of phosphorus concentrations to lower the likelihood of future blooms will require substantial action in both the watershed and in the reservoirs themselves. It will also require a commitment to water quality monitoring to identify sources, evaluate progress and foresee the potential for near term water quality problems that may affect treatability and delivery of high-quality water. It will also include monitoring the reservoirs for cyanobacteria throughout the open water season.

Table 6. Selected water quality data from Upper and Lower Artichoke Reservoirs, August 14, 2020.

Sample Identification/Site Location	Date	Time (24:00)	Turbidity NTU	Total Phosphorus (UNH) (υg/l)	Soluble Reactive Phosphorus (UNH) (υg/l)	Chlorophyll α (UNH) (υg/l)	Ammonia Nitrogen (Alpha) mg/l	Nitrate Nitrogen (Alpha) mg/l	Total Kjehldahl Nitrogen (Alpha) mg/l
Upper Artichoke Turkey Hill Rd	8/14/2020	16:00	21.8	71.0	2.2	86.5	ND[5]	ND[4]	0.761
SW-1 (Surface)	8/14/2020	12:15	12.1	42.3	0.9	41.7			
SW-1 (0-2M core)	8/14/2020	12:15	see profile	47.6	2.1	39.4	ND[5]	ND[4]	0.843
Upper Artichoke Dam Spillway	8/14/2020	14:15	11.1	52.5	2.1	45.9	ND[5]	ND[4]	0.958
Near Intake	8/14/2020	15:22	3.7	24.3	0.8	10.9	ND[5]	ND[4]	0.300

October 2020 Bloom (Indian Hill)

A small cyanobacteria bloom was observed in the Indian Hill reservoir on October 19, 2020. This bloom was a wind driven surface scum that accumulated on the leeward shore of the reservoir. Samples were collected for identification of the organisms and nutrient concentrations. One sample was collected in the scum for qualitative analysis, while quantitative samples were collected near the valve house and a second was collected 100 feet into the reservoir.

Both quantitative samples had similar composition except for the cyanobacteria, which were much more abundant in the sample from right next to the valve house than the sample 100 ft further into the reservoir (Figures 8 and 9). Synura, a golden alga that can cause taste and odor, was abundant in both, and there were various other algae present at lower densities. The cyanobacteria noted below were present mainly in the valve house sample; a little *Dolichospermum planktonicum* and *Dolichospermum lemmermannii* were present in the sample from 100 ft from the valve house, but not enough to be of any consequence. The count for the valve house sample was still below the 70,000 cells/mL threshold, although the count was substantial. The qualitative sample from the most concentrated scum site was certainly well in excess of the cell count threshold, but the areal and volumetric extents of the bloom were very limited. *Dolichospermum planktonicum* produced little toxin in Artichoke. *Dolichospermum lemmermannii* is more of a threat, commonly producing both liver and nerve toxins. All of the cyanobacteria from Indian Hill Reservoir are likely to have grown at the sediment-water interface then risen in the water column by forming gas pockets in cells. This is a common mode of bloom development, with bloom severity depending on how extensive the growth has been and how synchronously the rise is. The stalked ciliates attached to *Dolichospermum lemmermannii* are indicative of it having been growing on the bottom for quite some time (possibly a couple months). Nutrient concentrations from samples collected in conjunction with the phytoplankton/cyanobacteria samples support this observation. Phosphorus concentrations were much higher (75.9 µg/l) in the nearshore sample with numerous cyanobacterial cells than in the offshore sample with fewer cells (12.5 µg/l). It is likely that the cells pulled phosphorus from the sediments and carried the phosphorus up into the water column when they broke free and floated to the surface. As these nutrients are depleted, the bloom should dissipate. As discussed above, phosphorus concentration in Indian Hill on September 9, 2020 were the highest reported in recent years, likely contributing to the bloom.

While the presence of the cyanobacteria observed in Indian Hill was a concern, there was no immediate need for treatment or other action due to the scale of the bloom. Dilution of Indian Hill after discharge downstream into Upper Artichoke Reservoir and ultimately Lower Artichoke minimized any impact on the water withdrawal at the lower end of Lower Artichoke. However, the presence of the cyanobacteria and the abundant golden alga Synura do represent future threats to water supply, given that they could occur at higher levels at some point. As a measure of safety and to more fully characterize the bloom, toxicity samples were collected. Results are pending.

Examining both watershed and in-lake options for management opportunities should be continued to reduce the likelihood that bloom events recur.

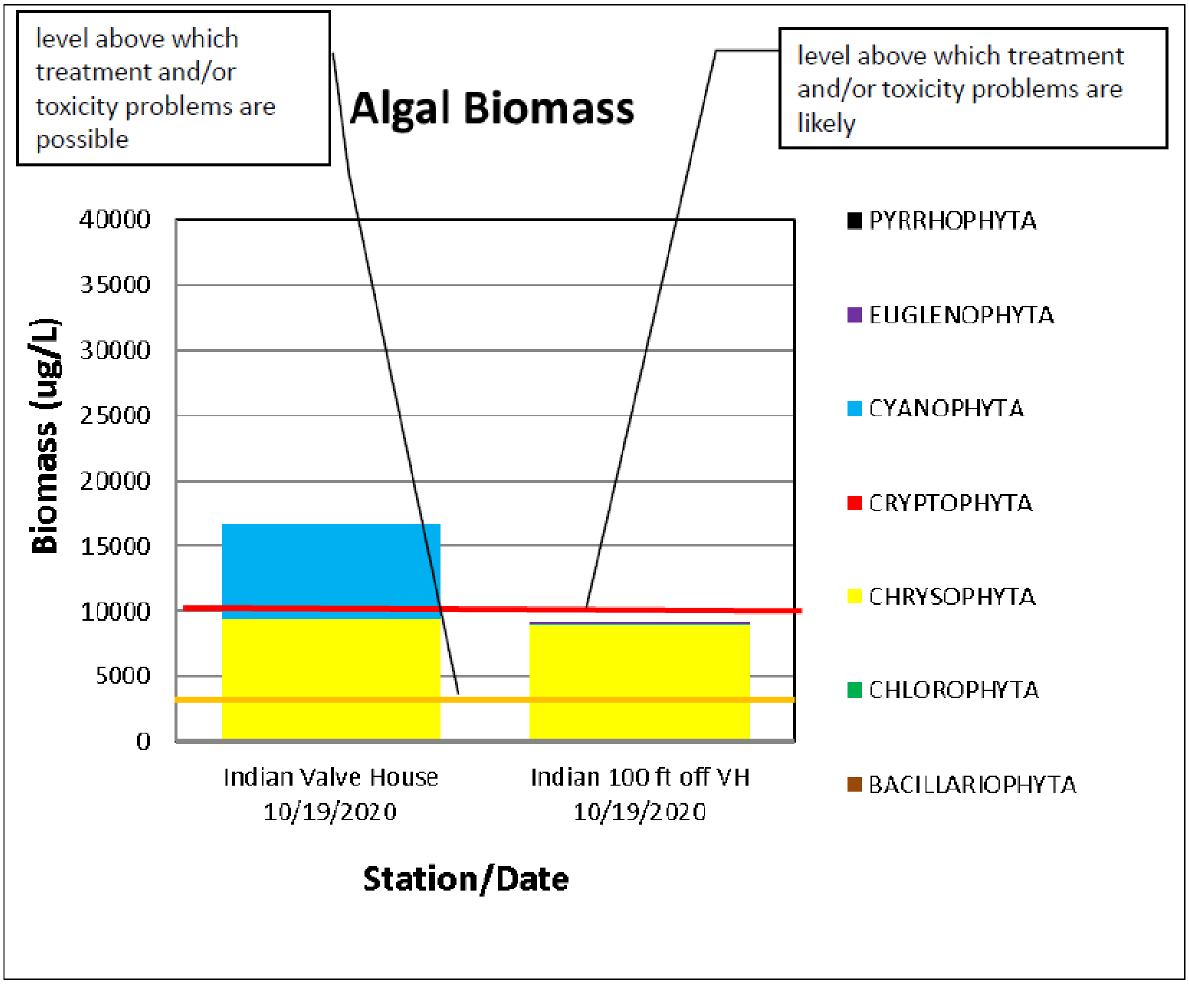


Figure 8. Algal biomass during October 2020 bloom in Indian Hill Reservoir.

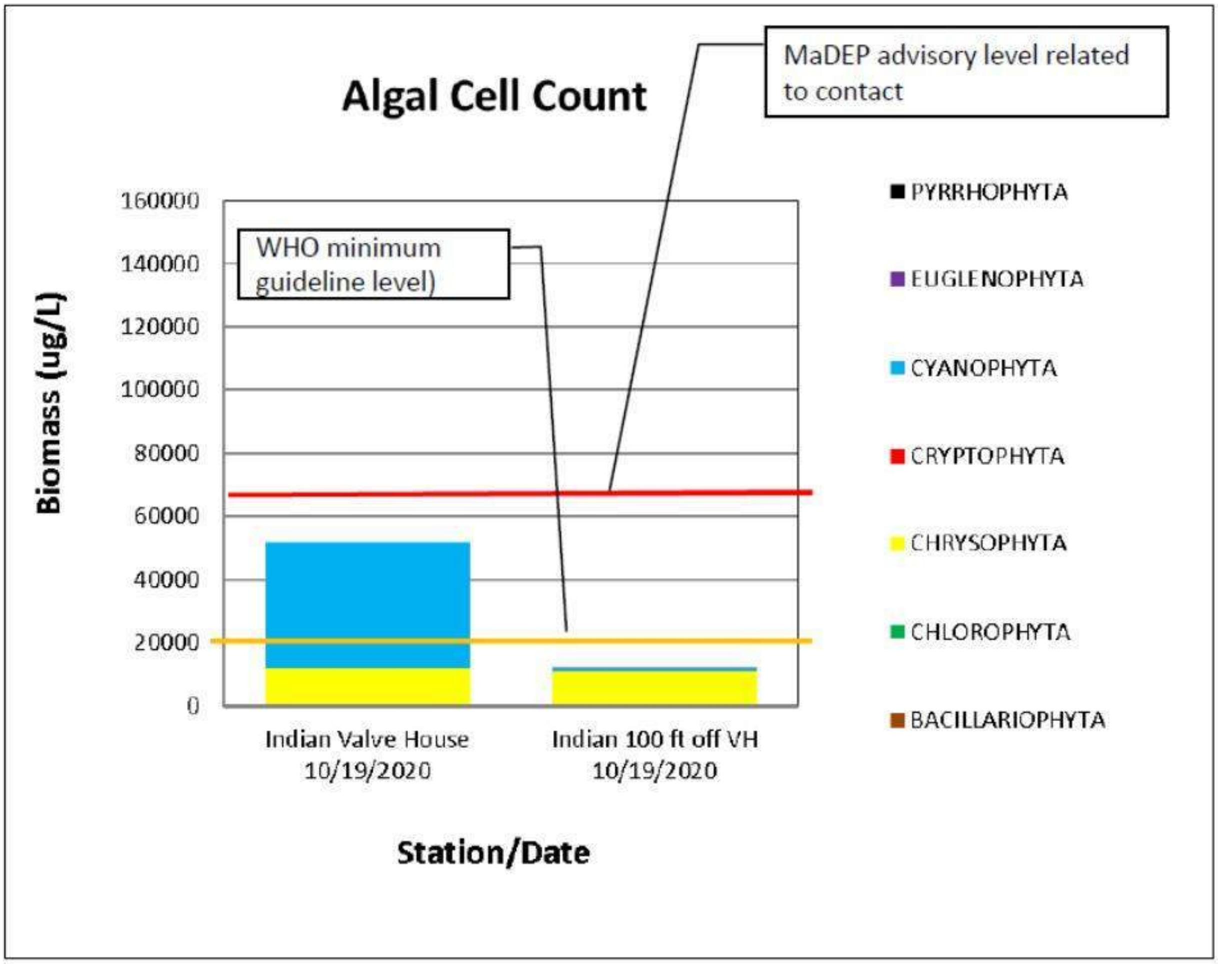


Figure 9. Algal cell count during October 2020 bloom in Indian Hill Reservoir.

Recommendations

Based on the review of the historic and current water quality data and observations made while at the reservoirs, the following recommendations for the future maintenance of reservoir water quality are made.

1) Water quality monitoring on the reservoirs should be continued to document the water quality conditions that are fueling the recent blooms until the blooms dissipate. This monitoring should include both cyanobacteria and water quality testing in the reservoirs and in the tributaries.

2) To evaluate the long-term ecological condition of the reservoirs, regular water quality monitoring should continue based on the recommendations of the AECOM (2016) plan and cyanobacteria monitoring as specified in the draft 2020 cyanobacteria monitoring plan (DKWRC 2020) for Newburyport. This should include both reservoir and tributary monitoring.

3) The watershed management recommendations in the 2016 plan should be implemented to the extent possible. Additional recommendations based on an adaptive management approach should be considered. Substantial reduction in watershed loading may be required to improve reservoir water quality.

4) In-reservoir management techniques and treatment plant changes may be considered if water quality data supports their use. An initial screening of alternatives considering recent water quality data will be a beneficial first step. Current water quality data and the physical characteristics of the reservoirs will help guide decisions. Candidate techniques from the initial screening can be further evaluated and costs estimates developed.

References

AECOM. 2016. Water Quality Study Report. Prepared for the City of Newburyport, NH

DKWRC. 2020. Newburyport Reservoirs Cyanobacteria Monitoring Draft. April 23, 2020.

Attachment A: 2019 and 2020 Water Quality Data

(see spreadsheet)

Attachment B: Upper and Lower Artichoke Phytoplankton 2020

(see spreadsheet)

Attachment C: Indian Hill Phytoplankton 2020

(see spreadsheet)

APPENDIX E

Newburyport Reservoirs Water Quality and Cyanobacteria Monitoring Plan for:

City of Newburyport, MA

January 2021

Rev 1.0

Prepared by:

DK Water Resource Consulting LLC
45 Red Brook Circle
Wolfeboro, NH 03894

Contents

1.0 Project Organization

The monitoring program will be administered by the City of Newburyport Water Division staff. There will be oversight and assistance provided by contractors hired by the city, as needed. It is expected that there will be collaboration between the staff, University of New Hampshire (UNH), members of the Cyanobacteria Monitoring Collaborative, Massachusetts Department of Environmental Protection (MassDEP) and independent contractors and laboratories retained by the city. These groups are expected to provide training and expertise as the Newburyport monitoring program evolves.

Table 1 presents a list of people who will receive the approved monitoring plan, monitoring plan revisions, and any amendments.

Table 1. Monitoring Distribution List and Project Roles and Responsibilities

Name	Project Role	Organization	Phone and/or E-mail
Tom Cusick	Superintendent, Project Manager/QA Officer	City of Newburyport	978 465-4466 TCusick@CityofNewburyport.com
Don Kretchmer, CLM	Monitoring Plan Preparation	DK Water Resources Consulting	603-387-0532 dkretchmer@metrocast.net
Christopher Hood	Assistant Superintendent	City of Newburyport	978 465-4466 CHood@CityofNewburyport.com
Peter King	Operator	City of Newburyport	978 465-4466 PKing@CityofNewburyport.com

2.0 Background

The City of Newburyport has a strong interest in maintaining high quality water in its surface water supply. Current and potential future water quality threats linked to both human activities (development, roads, agriculture) and natural processes and episodic events (i.e. intense storms, increased runoff and natural lake aging processes) can be evaluated using data collected through this monitoring plan.

Conversion of reservoir watershed land from forest to residential and roads or agricultural lands has the potential to increase the loading of nutrients (primarily phosphorus) to the reservoirs resulting in increases in aquatic plant, algae and cyanobacteria growth. Phosphorus from historic loading in the sediments at the bottom of the reservoirs can be released into the water column under certain conditions (lack of oxygen or direct uptake by algae, cyanobacteria and plants) adding to the current loading from the watershed.

More frequent, intense storms resulting in increased runoff and streambank erosion, increased soil temperatures, shorter frozen ground periods as well as major changes in forest composition and health due to climate change, wind, ice storms, disease or insect infestations also have the potential to increase the delivery of nutrients to the reservoirs from the watershed. Higher water temperatures, longer growing seasons and seasonally lower flushing rates due to prolonged droughts also have the potential to increase the magnitude and duration of elevated algal growth in the reservoirs and the potential formation of disinfection byproducts.

The risk for cyanobacteria (blue-green algae) blooms are of particular concern when phosphorus levels are elevated (Table 2). Based on recent water quality data, Indian Hill and Bartlett reservoirs are in the low bloom risk category although a small bloom was documented in Indian Hill Reservoir in the fall of 2020. Lower Artichoke is in the moderate risk category while Upper Artichoke is in the high-risk category. A large bloom originated in Upper Artichoke reservoir in August of 2020 and was subsequently observed downstream in Lower Artichoke reservoir.

Many cyanobacteria species produce toxins which can be problematic in drinking water. Occasional episodic disturbances or even prolonged incremental changes in water quality can ultimately affect water treatment effectiveness and the production of disinfection byproducts. Preserving excellent water quality through appropriate watershed protection and targeted in-reservoir measures is not only fiscally prudent by avoiding costly treatment upgrades but also enables the City to consistently provide safe and aesthetically pleasing water to its customers.

Table 2. Potential for cyanobacterial blooms in waterbodies based upon environmental factors (adapted from MassDEP 2018).

Bloom Risk level	History of Blooms	Water Temp °C	Total Phosphorous (in water) micrograms per liter (µg/L)	Thermal Stratification
Very low	No	<15	<10	Rare or never
Low	Yes	<15-20	<10	Infrequent
Moderate	Yes	20-25	10-25	Occasional
High	Yes	>25	25-100	Frequent and persistent
Very high	Yes	>25	>100	Frequent and persistent/strong
Based on Newcombe et.al., 2010				

Few data currently exist to describe the nutrient concentrations or cyanobacteria in the Newburyport Reservoirs watershed beyond those data collected as a part of the watershed planning efforts in 2015 and more recent data collected in 2019-2020. Recent cyanobacteria blooms in three of four reservoirs points to the need for more intensive monitoring in the Newburyport Reservoirs and watershed as a part of Newburyport's source protection program.

Collection of high-quality watershed and reservoir water quality monitoring data in conjunction with a program such as this serves several purposes. First, collection of water quality data allows tabulation of accurate loading estimates from the watershed and accurate modeling of reservoir concentrations. Second, collection of data allows identification of and ranking of sources to characterize loading and to inform the selection of appropriate structural and non-structural best management practices (BMPs) to address identified problems. Third, source water quality data are critical to optimal operation of the water treatment plant by providing advance notice of potential treatment challenges. Finally, a water quality monitoring program allows evaluation of effectiveness of existing and future treatment measures. This allows the water utility to adaptively manage the reservoirs and watershed and treatment process.

It is assumed that routine monitoring will be conducted by city employees with oversight and assistance from contractors as needed. Water quality sampling is proposed for specific locations in the reservoirs and watersheds. Monitoring will be conducted in accordance with the University of New Hampshire Lakes Lay Monitoring Program protocols (UNH 2016), the Cyanobacteria Monitoring Collaborative QAPP (USEPA 2017) and the MADEP guidance for cyanobacteria monitoring in public water supplies (MassDEP 2018). In-situ monitoring will be conducted, and samples collected will be analyzed for a variety of water quality parameters as discussed below. Because many of the parameters of concern are related to nutrient enrichment, an increased focus will be placed on parameters related to algal growth (nutrients) in addition to the traditional parameters used to evaluate treatment of the finished water.

3.0 Monitoring Design

In-reservoir monitoring will occur in the deep spot of each reservoir as soon as practicable after ice-out and monthly from mid-May through mid-October. After mid-October, monitoring should continue monthly until the reservoirs freeze. It is estimated that this will result in 8 reservoir monitoring events at four (4) locations over the course of a typical year. These data can be used to assess the variability of water quality in the reservoirs, detect seasonal changes and identify water quality conditions that may support future cyanobacteria blooms. Locations are described in Table 3 and depicted in Figure 1. A schedule is presented in Table 5. Every other reservoir sampling event will include the collection of a duplicate sample at a randomly selected station/depth. In reservoir monitoring will also include observation of the reservoirs for cyanobacteria blooms and contingency phytoplankton identification and toxicity testing. These programs are described further below.

Tributary monitoring will be conducted three times each year at a minimum. Monitoring will target three (3) separate runoff events roughly coinciding with spring, summer and fall depending on precipitation patterns. Since flow in many of the small tributaries is primarily storm related, monitoring will occur as soon as practicable after a rainfall of at least 0.25 inches or a period of snowmelt. One event will occur in spring prior to leaf-out. The second event will occur in the mid-summer and the third event will occur in the mid-fall. Typically, dry weather events would be an additional part of a tributary monitoring program however, observations of the tributaries around the reservoirs suggest most are intermittent and only flow when there is rainfall. Sample analyses will be performed by City of Newburyport, Alpha laboratories or the UNH LLMP lab in Durham, NH. This monitoring is expected to be shore based with grab sample collection. Locations are described in Table 4 and depicted in Figure 1. A schedule is presented in Table 5.

Consistently high readings of one or more parameter may trigger more monitoring events at a site(s), additional targeted investigation and/or sampling upstream in a tributary(s) to identify the source(s) of the high readings. The tributary monitoring consists of runoff monitoring at 17-25 tributary locations (Figure 1, Table 4).

It is not expected that each tributary station will be sampled during each event for the foreseeable future. Once a baseline of data has been collected, the station list may be reduced to a set of critical or representative stations. In addition, during any individual sampling event, some stations will be dry or inaccessible however, it is expected that each station located at the point of discharge to the reservoir will be visited during each monitoring event (baseline stations) until a baseline of data over a range of conditions is obtained. Upstream stations (contingency stations) which are a subset of the direct tributary stations will be sampled, if needed, to evaluate specific suspected sources. It is likely that additional contingency stations will be added as the program develops. Once suspected sources have either been determined to be not significant or have been remediated, sampling at the contingency stations can either cease or become much less frequent. Each tributary monitoring event will include a duplicate sample for every ten samples collected at randomly chosen locations.

Table 3. Reservoir Monitoring Stations

Monitoring ID #	Location Description	Category
S-1	Lower Artichoke Reservoir - deep spot	Baseline
S-2	Upper Artichoke Reservoir – deep spot	Baseline
S-3	Indian Hill Reservoir – deep spot	Baseline
S-4	Bartlett Reservoir – deep spot	Baseline

Table 4. Tributary Monitoring Stations

Monitoring ID #	Location Description	Category
Indian Hill Reservoir		
T3.5	Indian Hill Tributary-at reservoir	Baseline
T4	Indian Hill Tributary-at reservoir	Baseline
T5	Indian Hill Tributary-at reservoir	Baseline
T6	Indian Hill Tributary-at reservoir	Baseline
T7	Indian Hill Tributary-at reservoir	Baseline
T8	Indian Hill Tributary-at reservoir	Baseline
T12	Indian Hill Tributary-at reservoir	Baseline
T6.5	Indian Hill Tributary-upstream of T6	Contingency
T13	Indian Hill Reservoir-upstream of T4	Contingency
Upper Artichoke Reservoir		
SW-1	Upper Artichoke- lower in-reservoir	Baseline
SW-2	Upper Artichoke- upper in-reservoir	Baseline
Off 163	Upper Artichoke Tributary - at reservoir	Baseline
T1	Upper Artichoke Tributary - at reservoir	Baseline
T3	Upper Artichoke Tributary - at reservoir	Baseline
T3	Upper Artichoke Tributary - at reservoir	Baseline
T16	Upper Artichoke Tributary - at reservoir	Baseline
T19	Upper Artichoke Tributary - at reservoir	Baseline
T2	Upper Artichoke Tributary – upstream of reservoir	Contingency
T9	Upper Artichoke Tributary – upstream of reservoir	Contingency
T14	Upper Artichoke Tributary – upstream of reservoir	Contingency
T15	Upper Artichoke Tributary – upstream of reservoir	Contingency
T17	Upper Artichoke Tributary – upstream of reservoir	Contingency
T18	Upper Artichoke Tributary – upstream of reservoir	Contingency
Lower Artichoke Reservoir		
T11	At Upper Artichoke Dam-inlet to Lower Artichoke	Baseline
Bartlett Pond		
T10	Bartlett Pond Tributary – at reservoir	Baseline

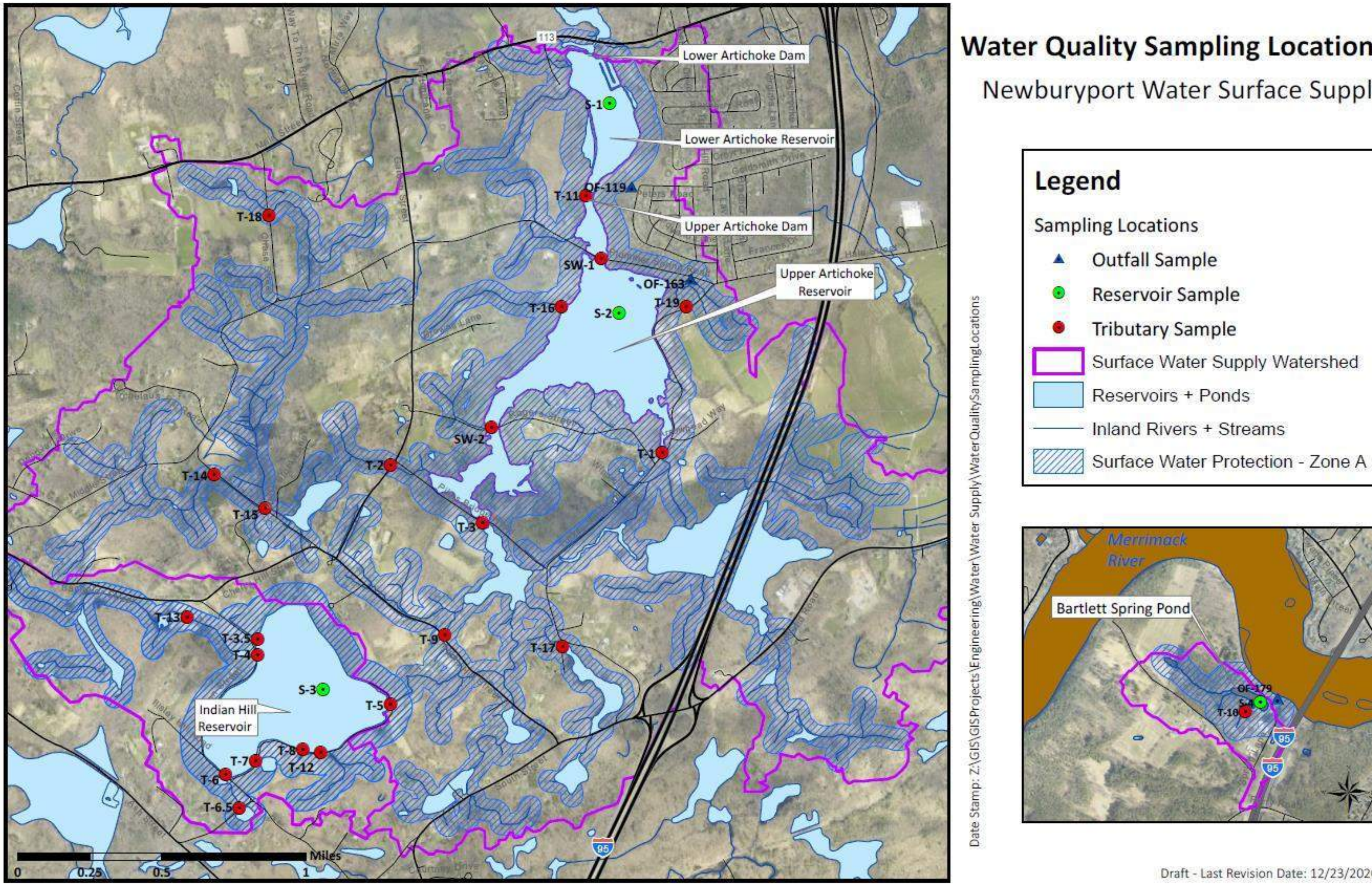


Figure 1. Newburyport Reservoir Sampling Locations

Table 5. Baseline Monitoring Schedule

Target Period	Frequency	Target Conditions	Location
Ice-free season	Twice weekly	BloomWatch-all conditions	Reservoirs
Within 2 weeks of ice out	Once/yr	Spring turnover-well mixed	Reservoir stations
Spring	Once/yr	Pre leaf-out spring runoff	Tributary stations
May through mid-October	Monthly	Growing season	Reservoir Stations
Summer	Once/yr	Summer rain event	Tributary Stations
Late fall	Once/yr	Fully mixed pre-winter	Reservoir Stations
Late summer/early fall	Once/yr	Fall runoff event	Tributary Stations

3.1 Baseline Monitoring

Twenty-one (21) sites have been identified as baseline monitoring stations (Tables 3 and 4). Most of these stations, shown in Figure 1 were monitored as part of the baseline monitoring program conducted for the watershed plan in 2015 and again in 2019-2020. These include four (4) mid-reservoir deep stations, 14 tributary locations and three (3) reservoir locations where roads cross the reservoirs (SW-1 and SW-2) or a dam discharge directly feeds a reservoir (T11). Monitoring parameters are described in Table 6. Samples for laboratory analysis will be collected in accordance with the latest UNH LLMP QAPP protocols (UNH 2016) and the Cyanobacteria Monitoring Collaborative QAPP (USEPA 2017) which are summarized below. Parameters to be analyzed in reservoir and tributary water samples are presented in Tables 6 and 7. Monitoring protocols can be found in the latest UNH LLMP QAPP (UNH 2016).

Reservoir monitoring will occur throughout the open water season and may coincide with the tributary events if conditions allow. BloomWatch monitoring will occur twice weekly throughout the ice-free season. A full suite of monitoring parameters and samples will be collected as soon as practicable after ice-out, monthly from May through mid-October and once from mid-October until ice-in. When the reservoir is stratified (defined as a temperature difference of >4 °C between surface and bottom), both an epilimnetic core and a deep sample will be collected from each reservoir. Samples for laboratory analysis will be collected in accordance with the latest UNH LLMP QAPP protocols (UNH 2016, Appendix A) which are summarized below.

Cyanobacteria related parameters are to be included as part of the monitoring program. Protocols should follow those listed in the Quality Assurance Program Plan (QAPP) for the Cyanobacteria Monitoring

Collaborative Program (USEPA 2017) (Appendix B). Specifically, protocols for the BloomWatch (Tier 1- visual assessment) will be followed twice a week while CyanoScope (Tier 2- plankton identification) and CyanoMonitoring (Tier 3 – toxicity testing) will be followed at reservoir stations monthly from May through October, once within 2 weeks of ice out and once from mid-October to ice-in. Recommended elements of a baseline cyanobacteria monitoring program are presented in Figure 2.

Table 6: List of Parameters for the Newburyport Reservoir Monitoring Program with laboratory responsibility.

Reservoir Stations	
Laboratory Parameter	**Field Parameter**
UNH Laboratory	Temperature (T) (profile)
Chlorophyll a (chlor a) (epilimnetic core only)	Dissolved Oxygen (DO) (profile)
Dissolved color	pH (from epilimnetic core)
Total phosphorus as P (TP)	Secchi transparency
Contract or City Laboratory	Specific Conductance (profile)
Iron	Turbidity (from epilimnetic core)
Manganese	BloomWatch observations
Ammonia as N	Phycocyanin (0-3 m core)
Nitrite plus nitrate as N	
Total Kjehldahl Nitrogen (TKN) as N	
TN/TP ratio (calculated)	
Organic nitrogen (ON = TKN - Ammonia)	
Total nitrogen as N (TN = ON + (Nitrite + Nitrate))	
Total organic carbon as (TOC)	
CyanoScope (epilimnetic net tow)	
CyanoScope (cyanobacteria ID & cell numbers 0-3m core)	
CyanoMonitoring (cyanobacteria toxins 0-3m core)	

Table 7: List of Parameters for the Newburyport Tributary Monitoring Program with laboratory responsibility.

Tributary Stations
UNH Laboratory
Total phosphorus as P (TP)
Contract or City Laboratory
Ammonia as N
Nitrite + Nitrate as N
Total Kjehldahl Nitrogen (TKN) as N
TN/TP ratio (calculated)
Organic nitrogen (ON = TKN - Ammonia)
Total nitrogen as N (TN = ON + (Nitrite + Nitrate))

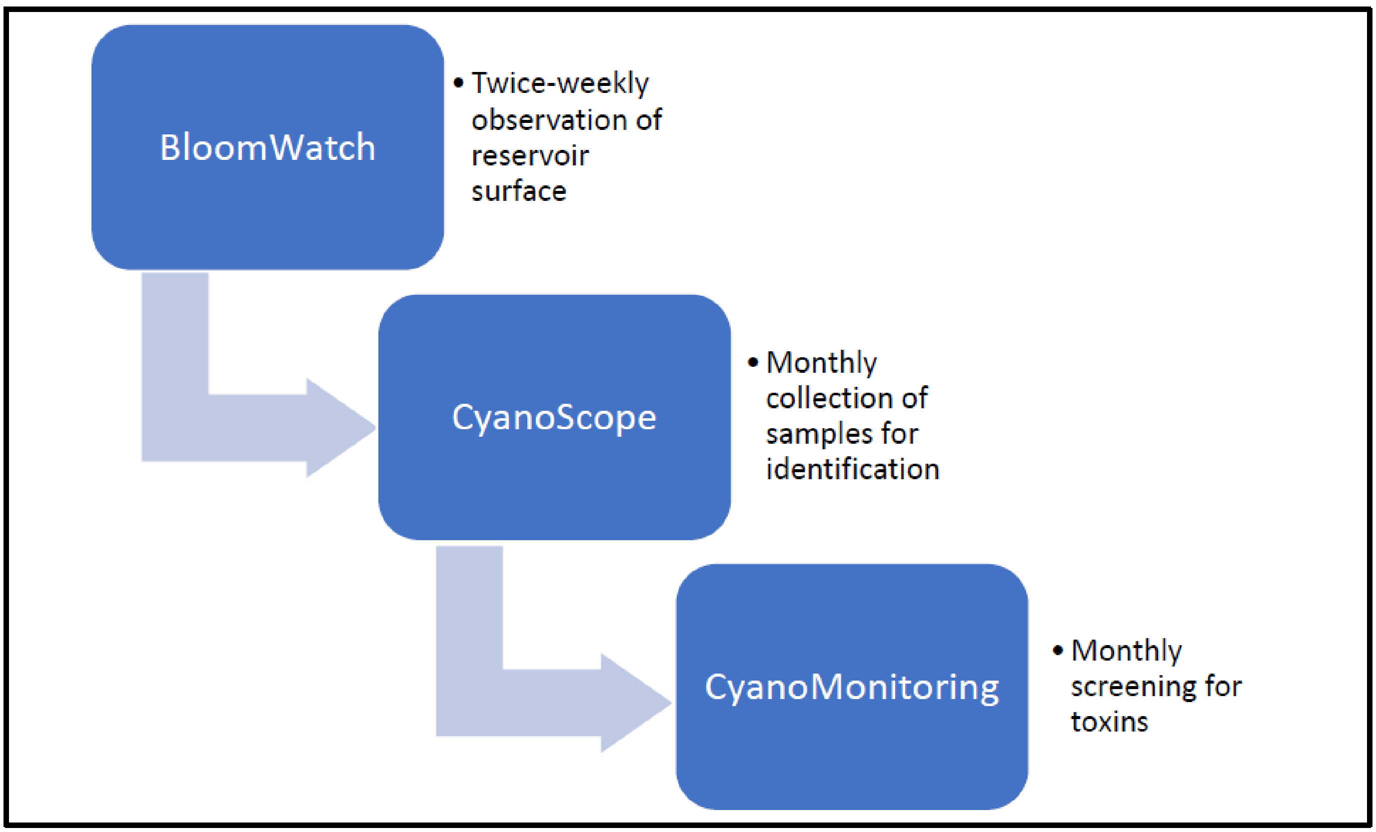


Figure 2. Recommended routine elements of cyanobacteria monitoring program for Newburyport Reservoirs.

3.2 Contingency Monitoring

At times, unanticipated conditions in the Newburyport Reservoirs watershed will trigger additional monitoring effort. In nearly all instances, the additional monitoring will result in an increase in frequency of monitoring effort until the underlying conditions return to baseline levels or below. Some of the more likely scenarios are detailed in Table 8 below with suggested responses. Cyanobacteria triggers and responses are depicted in Figure 3.

Table 8. Contingency Monitoring Triggers and Actions

	Trigger	Response
1.	BloomWatch Observations suggest a bloom is in progress.	Collect samples for CyanoScope analysis at the site of the bloom and determine if Cyanobacteria are causing the bloom.
2.	Cyanobacteria bloom is confirmed in one of the reservoirs through Bloomwatch and CyanoScope protocols.	Collect CyanoScope and CyanoMonitoring samples in the reservoir and downstream reservoirs to the intake.
3.	CyanoScope analysis indicates the presence of a toxin forming species of cyanobacteria.	Complete BloomWatch observations daily until the bloom dissipates. Conduct cyano-monitoring toxicity testing on core sample from the reservoir, near intakes and raw and finished water.
4.	Presence of cyanotoxins confirmed	Continue monitoring for cyanotoxins twice weekly until concentrations decline.
5.	Tributary samples are consistently elevated with respect to one or more parameters.	Investigate upstream for sources. Consider collecting samples at both sides of the next upstream stream junction to determine which branch is the cause of the elevated concentration.

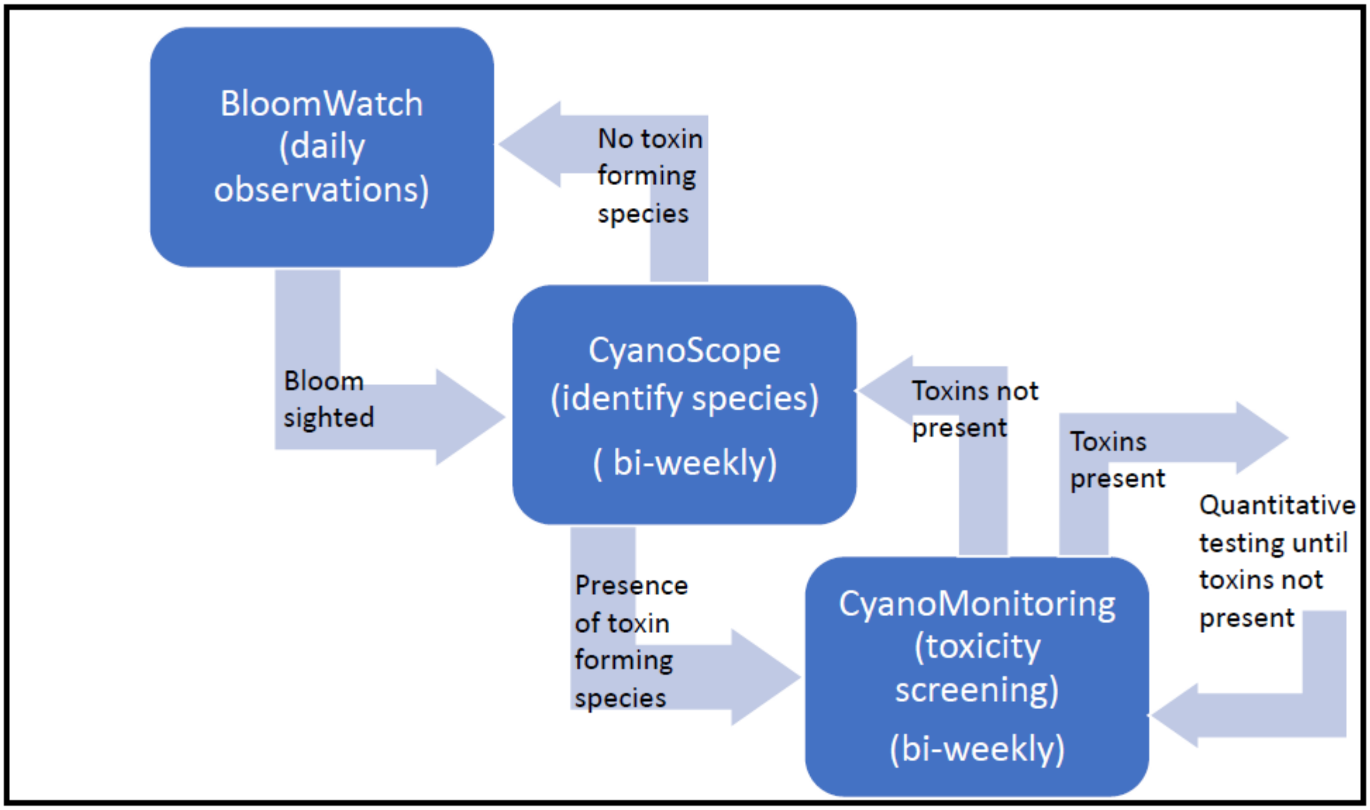


Figure 3. Contingent monitoring for cyanobacteria monitoring program for Newburyport Reservoirs.

Should a potential bloom be sighted as a part of the BloomWatch Program, a sample or samples should be immediately collected at the point of observation (likely nearshore) for the CyanoScope program to identify the species or groups of species responsible for the bloom (see Section 4.4 for sample collection procedure). Screening level (qualitative) testing should be completed on samples by Newburyport staff using ELISA tests or the equivalent. At the same time, a contingency sample or samples should be collected for quantitative analysis at an outside laboratory (CyanoMonitoring) each time a qualitative sample is collected. Should potentially toxin forming species be observed in the CyanoScope sample and/or screening toxicity testing (ELISA or equivalent) be positive for toxins, the CyanoMonitoring sample should be submitted for quantitative toxicity analysis to a laboratory based on protocols in Appendix B. Current advisory levels are summarized in Table 9.

Table 9. US EPA DW Health Advisories (adapted from MassDEP 2018)

Cyanotoxin	**US EPA 10-day HA**	
	Bottle-fed infants and pre-school children	School-age children and adults
Microcystins	0.3 µg/L	1.6 µg/L
Cylindrospermopsin	0.7 µg/L	3 µg/L

BloomWatch monitoring should be conducted daily throughout the course of the bloom, CyanoScope and CyanoMonitoring sampling should be repeated daily nearshore if the bloom has been concentrated by the wind as well as by 0-3 meters (or to depth of water, whichever is less) core at the deep location in the reservoir until the bloom is not detected.

Contingency downstream monitoring. A confirmed potentially toxic bloom in an upstream reservoir would trigger more detailed monitoring including BloomWatch, CyanoScope and CyanoMonitoring in the next downstream reservoir (if applicable) at the point where water enters from the upstream reservoir and by 0-3-meter core at the deep spot or at the raw water intake. For example, a bloom confirmed in Lower Artichoke would trigger sampling of the raw water from the intake but would not trigger additional sampling in Indian Hill or Upper Artichoke unless a bloom was suspected there as well.

If a bloom is suspected, the PWS Bloom Tracking Form https://www.mass.gov/doc/public-water-system-bloom-tracking-form/download found in Appendix C should be filled out and returned to MassDEP.

3.3 Future Monitoring Recommendations

Monitoring of the Newburyport reservoirs and watershed should be continued for the foreseeable future however, the intensity of the monitoring effort is dependent on the findings. The minimal plan, consistent with other water utilities with surface water supplies should include a combination of parameters designed to assist with treatability of the raw water and parameters to measure trophic state or the relative fertility of the reservoirs. Increases in the concentrations of parameters related to trophic state may lead to more serious long-term ramifications for the water supply including increases or changes in treatment, the presence of harmful algal blooms (cyanobacteria), depression of oxygen at depth in the reservoirs and a more favorable environment for invasive aquatic species, particularly plants.

Given the recent history of blooms in the reservoirs, it is advised that several years of the baseline monitoring be undertaken prior to a re-evaluation and modification of sampling frequency or parameters. This will give the city a much better picture of the seasonal dynamics of the reservoirs and the interplay between water chemistry and blooms.

In addition to routine monitoring, consideration should be given to installing staff gages in the major tributary streams and establishing stage discharge curves for these gages. This will allow flow to be estimated during future monitoring events.

4.0 Monitoring Protocol

This project Standard Operating Procedure (SOP) defines the procedures for the collection of water samples from a shore-based station and an in-lake station. The collection of water samples is limited to the parameters described in Tables 6 and 7.

4.1 Health and Safety Considerations

Daily safety briefs are to be conducted at the start of each monitoring event before any work commences. These daily briefs are to be facilitated by the monitoring coordinator or his/her designee to discuss the day's events and any potential health risk areas covering every aspect of the work to be completed. Weather conditions are often part of these discussions. Everyone on the field team has the authority to stop work if an unsafe condition is perceived and not resume work until the conditions are fully remedied.

The following guidance on safety is taken directly from MassDEP (2018) with respect to sampling of cyanobacteria:

> "Because of the potential cyanotoxins that cyanobacteria may produce, MassDEP recommends that operators take the following precautions when responding to a CyanoHAB (cyanobacteria hazardous algal bloom) event with particular care taken when collecting any samples:

- Avoid direct and indirect skin and eye contact with water and scum, by wearing appropriate personal protective equipment (PPE) that may include: safety glasses or goggles, gloves, protective clothing (Tyvek suits, apron, etc.), and safety boots or waders (depending on where the sampling will be done). At a minimum, PPE selection should be based on the hazards likely to be encountered during the sampling activities.
- Skin contact with a scum, contaminated or potentially contaminated water should be rinsed immediately with clean water.
- Avoid ingesting water and scum; do not eat or drink while sampling.
- Avoid falling into the water by wearing safety boots or waders (depending on where the sampling will be done).
- Avoid going into the water if possible, use an extendible sampling pole if available.
- Do not attempt to wade into a stream for which values of depth multiplied by the velocity equal or exceed 10 ft^2/s. If wading into the water is required, wear a personal flotation device (PFD), and use a wading rod during wading activities.
- If samples are to be preserved, care should be taken when adding and using Lugol's solution (gloves and eye protection should be used as it can be an irritant to the skin and eyes).
- Decontaminate sample bottles before storing for transport, sampling equipment, re-usable PPE and any contaminated surfaces as soon as possible.
- Properly dispose of any waste including disposable PPE.
- Wash hands with soap and water after removing PPE."

4.2 Equipment and Materials

The equipment list in Table 10 contains materials which may be needed in carrying out the procedures contained in this monitoring plan. Not all equipment listed below may be necessary for a specific activity. Additional equipment may be required, pending field conditions.

Table 10. Monitoring Equipment List

Water sample containers.
Sample Bottle Labels
Sample collection forms (Appendix A)
Field logbook (optional)
Dipper with long handle
Chain of Custody forms (Appendix B)
YSI multiparameter water quality meter (or equivalent) equipped with Dissolved Oxygen, Temperature and Specific Conductance sensors.
Secchi Disk and line
Turbidity meter
pH meter
Phycocyanin/chlor *a* fluorometer
Integrated tube sampler (for epilimnetic core)
Alpha Bottle (or equivalent)
Boat and boat related safety equipment
Anchor and line
Depth sounder (optional)
3m integrated tube (for CyanoScope (identification/enumeration) and CyanoMonitoring (toxicity)
Plankton Net (for identification)
Squeeze bottle for rinsing plankton net.
250 ml plastic beaker for in-situ field readings

4.3 Routine Water Sample Collection Procedures

Sample collection information will be recorded at the time of collection using either standardized forms, a field logbook, or a combination. This information will include, but not be limited to, the station ID, time and date of sample collection, the sampler's name, and any pertinent observations on weather, rainfall, presence of wildlife or waterfowl and other circumstances potentially relevant to water quality. A sample data sheet is provided in Appendix D.

Sample bottles are labeled in the field with waterbody name/town, sample location, sample date, sample time, and the collector's initials. Monitoring procedures will follow the University of New Hampshire Lakes Lay Monitoring Program protocols (UNH 2016), the Cyanobacteria Monitoring Collaborative protocols (USEPA 2017) and the MADEP guidance for cyanobacteria monitoring in public water supplies (MassDEP 2018). Those protocols are summarized below but the original reference should be consulted for detailed field procedures.

BloomWatch observations will be made twice weekly throughout the open water season. Observations at each reservoir should be made along the downwind shore of each reservoir.

In-lake monitoring will consist of field measurements of Secchi depth transparency, turbidity, pH, phycocyanin and chlorophyll as well as performing temperature/dissolved oxygen/specific conductance profiles at 0.5-meter intervals (starting at the surface) at the deep spot locations in each reservoir. Protocols are summarized in Table 10. Water quality samples will be collected at these deep stations. If the temperature profile indicates that the reservoir is stratified (greater than 4 °C difference between surface and bottom temperatures), samples will be drawn by a core of the epilimnion (thermocline defined as a greater than 1°C drop in temperature for a 1-meter change in depth). If the water column is not stratified and/or the water depth is < 2M, a sample will be collected from a depth of 0.5M by submerging a sample bottle upside down and turning it over at 0.5M until it fills. Sampling bottles with preservative should be filled in the boat with water drawn from other non-preserved bottles. Sampling steps for reservoir monitoring are summarized in Table 10. Core samples for phytoplankton identification (CyanoScope) and toxicity testing (CyanoMonitoring) will be collected from a 3-meter core unless there is insufficient water depth. If depth is insufficient, a sample will be collected from the entire water column taking care to not disturb the sediments.

Tributary monitoring protocols are presented in Table 11. If collecting samples from an open tributary channel: 1) Direct fill bottles at the station or use a dipper to collect sample from the main portion of the flow. Rinse dipper three times with sample water at the point of collection then collect sample. Take care not to disturb sediments in the channel upstream of the sample collection location. Pre-labeled sample bottles should be filled directly from the dipper. 2) Samples should be stored on ice in the dark.

Table 10. Reservoir station sampling instructions.

Step	Action
1. Arrive at station	Use GPS and map to locate in-lake station
2. Record station depth	Use fathometer or weighted line to record depth
3. Anchor	Lower anchor carefully to bottom. Release a minimum of rope to equal 1.5

	times the water depth
4. Site conditions	Record site conditions including wind, cloud cover, time and field crew participants
5. Transparency	Determine Secchi transparency (remove sunglasses, shady side of boat)
6. Complete profile	Use YSI to complete the water quality profile starting at the surface and then at 0.5 M intervals for dissolved oxygen, temperature and specific conductance.
7. Determine epilimnetic depth	Using profile data, determine epilimnetic depth
8. Collect integrated samples	0-3 meters for CyanoScope and CyanoMonitoring with smaller diameter tubing, epilimnetic depth with larger diameter tubing for water quality. Fill 1-liter Amber plastic bottle, mix and then fill all sample bottles from the 1-liter bottle. Refill the 1-liter bottle with full cores as needed to retrieve sufficient volume. Fill 1-liter bottle after all bottles have been filled and place in cooler (to be filtered for chlorophyll *a* and color). If stratification is not present and/or water depth is < 2M, collect water sample at 0.5 meters and do not collect deep sample. Collect CyanoScope and CyanoMonitoring samples from 0-3m or water depth whichever is greater taking care to avoid sediment contact.
9. Phycocyanin/chlor a	Use aliquot of 0-3-meter core for phycocyanin and chlorophyll a measurement
10. Turbidity and pH	Measure turbidity and pH from epilimnetic core sample (1-liter bottle)
11. Collect net sample 0-3 meters for phytoplankton identification	Lower net to 3 meters and retrieve slowly through the water column. Rinse plankton to bottom of net using squeeze bottle and empty into jar.
12. Collect hypolimnetic sample	Collect sample using Alpha bottle 1.5 meters from the bottom if water column is stratified. Fill all appropriate bottles from Alpha bottle.
13. Check all bottles and field sheet.	Check that all collections have been made
14. Lift anchor	Move to next site.

Table 11. Tributary station sampling instructions.

Step	Action
1. Arrive at station	Use GPS to locate tributary station
2. Site conditions	Record site conditions including wind, cloud cover, time and field crew participants
3. Collect water quality samples	Fill bottles from tributary surface
4. Check all bottles and field book/sheet.	Check that all collections have been made

All samples should be placed on ice in the dark and delivered to the laboratory in Newburyport, MA. Samples to be analyzed by UNH and/or a contract laboratory(s) should be preserved and delivered to the lab(s) within the prescribed holding time. Samples should be accompanied with standard Chain of Custody forms (Appendix E). If using contractor services, the laboratory will provide you with sample bottles, specific preservation volumes and instructions.

4.4 Collecting a Cyanobacteria Water Sample (wading and from a boat)

Cyanobacterial blooms are most often first observed in quiet bays or washed up along the shore at the downwind side of a reservoir. Grab samples taken directly from these areas can be obtained by wading into the water to approximately knee depth. While standing in place until any sediment that was initially stirred up has settled, uncap an amber, plastic, 250 ml (typical minimum volume) bottle, invert the bottle, push it through the water column to a depth of approximately 9 inches (0.25 meters), bring back up and recap the bottle. DO NOT just skim the water surface when collecting the sample or push any floating surface material away prior to sampling as this will skew the results teither positively or negatively potentially losing valuable information. Since cyanobacterial blooms (and algal blooms in general) are often patchy and at other times uniformly distributed, multiple samples collected from additional shore locations around the reservoir is ideal.

Open water sampling is generally a better predictor of the water body's algal population. A boat is necessary to sample the open water of a reservoir, and sometimes may be necessary for sampling around the DW facility intake. Sampling around the intake and from the raw water tap within the treatment plant is particularly important in determining the cyanobacteria population that may enter the plant as well, while the raw water tap is an option for systems that do not have access to a boat. Samples collected in open water and around the intake may be collected as integrated depth samples using an integrated tube sampler, or at specific depth(s) using a Alpha water sampler (a device used for collecting water samples at depth). Open water sample collections that utilize an integrated tube sampler should be lowered into the water column from the surface to a depth of three meters (which is fairly representative as the depth to sunlight penetration that supports primary production and development of bloom forming cyanobacteria). Discrete depth samples are recommended around the intake to better ascertain the cyanobacteria population at specific depths, particularly for systems that have the ability to alter intake levels.

Samples that will be examined and counted within 24 hours of sample collection do not require any preservation but should be stored on ice (never frozen) for transport and then refrigerated and kept in the dark until identification and enumeration. To ensure that samples held over 24 hours remain in a condition suitable for the identification and enumeration of cyanobacteria, a sufficient volume of Lugol's iodine preservative solution should be added at the time of collection. If using contractor services, the laboratory will provide you with specific preservation volumes and instructions. Samples preserved at the time of sampling in the field do not require additional treatment (e.g., chilling) prior to enumeration, but PWSs should follow their specific laboratory instructions.

All sample bottles should be appropriately labeled with a unique identification number that identifies the date and time of sample collection, along with a completed Chain of Custody (COC) form for contracted services. Systems utilizing in-house expertise for microscopic identification and enumeration should already have an SOP in place that dictates sample collection and all required record keeping.

4.5 Project Quality Objectives and Quality Control

The utility of cyanobacteria monitoring data, and the confidence in decisions made based on those data, are only as strong as the data collection efforts and analyses. USEPA (2017) provides a tiered program for monitoring cyanobacteria. The goal of the program in the Newburyport Reservoirs is to detect and react to the presence of potentially toxic cyanobacteria before they enter the raw water supply. The observations and analyses used in this program should be repeatable and consistent over time.

Water quality training should be completed through the University of New Hampshire Lakes Lay Monitoring program or equivalent training conducted by a contractor. Cyanobacteria training of staff should be completed through the US EPA sponsored Cyanobacteria Monitoring Collaborative or equivalent prior to implementation of each of the elements of the program namely BloomWatch, CyanoScope and CyanoMonitoring.

Field duplicate samples should be collected at 10 % of the stations visited or at least once per sampling round. These duplicate sample bottles should be unmarked as to location and time of collection and analyzed in in-house or at contract laboratories with other samples. The location and time of the sample should be recorded in the field book or on a data sheet for later reference. Additional quality control should be conducted by the laboratories. These tests may include laboratory blanks, spikes and interference analyses.

Quality control reviews for the monitoring will be performed by City of Newburyport staff who are not directly involved in the monitoring. This review will include review of procedures, sample locations, sample handling, field notes and chain-of -custody forms. All QA/QC issues identified will be properly documented, along with the appropriate steps taken to resolve the issues.

5.0 Schedule and Reporting

The following deliverables will be provided to the City of Newburyport Project Manager, during the project period. All deliverables will be placed on file at the Water Treatment Plant

- Monitoring plan. Winter **2021**
- Documentation of any updates for data and/or methods. – **as needed**
- Annual data summary – **Fall/Winter following each year of monitoring**

The Project Manager will submit reports documenting all work performed.

6.0 References:

DKWRC. 2018. Newburyport Reservoirs Cyanobacteria Monitoring Plan. Prepared for the City of Newburyport Public Works Department.

MassDEP. 2018. Cyanobacteria and Public Water Systems, MassDEP Guidance (updated October 2020). MassEOEEA and MassDEP.

NHDES. 2017. CyanoHAB Response Protocol for Public Water Supplies. April 18, 2017.

United States Environmental Protection Agency. 2017. Quality Assurance Program Plan (QAPP) for the

Cyanobacteria Monitoring Collaborative Program. Office of Measurement and Evaluation, North Chelmsford, Ma.

University of New Hampshire. 2016. Quality Assurance Project Plan for Water Quality Monitoring and Lake Surveys. New Hampshire Center for Freshwater Biology and Lakes Lay Monitoring Program.

Appendix A

University of New Hampshire LLMP

Quality Assurance Program Plan

(under separate cover)

Appendix B

Cyanobacteria Monitoring Collaborative

Quality Assurance Program Plan

(under separate cover)

Appendix C

Massachusetts Department of Environmental Protection

Bloom Tracking Worksheet

Massachusetts Department of Environmental Protection

Bureau of Water Resources – Drinking Water Program

PWS Bloom Tracking Form

Introduction

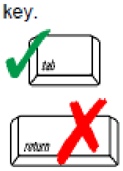
This algae-bloom tracking form was created as a technical assistance tool intended to support Public Water Systems (PWSs) with identifying and tracking all algae blooms, including potential cyanobacterial harmful algal blooms (CyanoHABs) within their surface water source(s). MassDEP encourages all PWSs with surface water sources to routinely monitor their reservoirs (ponds or lakes) for any changes, and recommends recording all algae or potential cyanobacterial (blue-green) blooms observed. The information obtained by completing this form during events, and tracking the information internally over time, will help better assess the risk to your PWS treatment facility, aid in appropriate response efforts, and support both in-source treatment applications and/or in-plant treatment process changes if necessary.

For assistance with completing this form, please contact Kristin Divris of the Water Utility Resilience Program (WURP) at 508-849-4028 or kristin.divris@mass.gov, your MassDEP Regional Office, or the Drinking Water Program as listed below:

NERO (Wilmington): Amy Lachance – 978-694-3260
SERO (Lakeville): Richard Rondeau – 508-946-2816
CERO (Worcester): Robert Bostwick – 508-849-4036
WERO (Springfield): Deirdre Doherty – 413-755-2148
DWP Drinking Water Program at program.director-dwp@mass.gov, subject: PWS Bloom Tracking

A. PWS Information

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.



PWS ID ____________ PWS Name ____________

Source location name & ID # ____________

Name of person completing form ____________

Name, phone number & email of person reporting bloom to PWS (if applicable) ____________

B. General Bloom Information

1. ____________ Date bloom initially observed
2. ____________ Time bloom observed
3. Attached map with bloom location noted (e.g., Google Map image): ☐ Yes ☐ No
4. Digital photos collected? (MassDEP highly encourages including digital photographs of any suspected blooms in close-up and landscape formats to assist with identification.)

   ☐ Yes ☐ No
5. Weather observations:

   a. ____________ Air temperature

   b. ____________ Wind direction

   c. Precipitation: ☐ Yes ☐ No

   d. ____________ Surface water conditions

   e. ____________ Other (describe)

IMPORTANT: Note 1: If a resident has reported a bloom to the PWS, then PWS staff should observe the source, suspected bloom, and plant conditions to record applicable information. This information may be maintained internally to document trends and made available to MassDEP upon request.

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Massachusetts Department of Environmental Protection
Bureau of Water Resources – Drinking Water Program

PWS Bloom Tracking Form

B. General Bloom Information (Cont'd)

IMPORTANT:
Note 2:
Staff Safety
Staff examining any algae bloom should take appropriate safety precautions to avoid direct contact. Any examination or sampling of blooms should be done with gloves and safety goggles to protect exposed skin and eyes. Masks are recommended to avoid inhalation of water spray caused by boats, wind or other water surface disturbances.

6. Bloom description:

a. Describe the location of the bloom in the surface water source with easily identifiable landmarks if possible (e.g., northern side of reservoir, at boat dock, etc.)

____

b. Identify approximate size of the bloom (sq. ft.) and the extent of the area affected (e.g., entire reservoir, shoreline accumulation, etc.)

____

c. Identify any color(s) observed in the water column:

☐ Green ☐ Blue ☐ Red ☐ Rust ☐ Brown ☐ Milky white ☐ Purple ☐ Black

____
Other color (description)

d. Identify any odor(s) observed in the source water: ☐ Earthy/musty ☐ Fishy ☐ Other

____
Other odor (please describe)

e. Identify if a surface scum is present (an accumulation at the surface) or if algae is floating near the water surface. (Algal blooms floating at the surface can look like grass clippings, green cottage cheese curds, or spilled paint.)

☐ Yes ☐ No ☐ Uncertain

f. Visually examine the bloom to determine if it may or may not be a potential CyanoHAB:

MAY BE A CyanoHAB

Material consists of small particles	☐ Yes	☐ No
Material is collecting in a layer on the surface or along a shoreline	☐ Yes	☐ No

NOT A CyanoHAB

Material has any leaf-like structures	☐ Yes	☐ No
Material can be lifted out of the water on a stick	☐ Yes	☐ No
Material is firmly attached to plants, rocks, or bottom	☐ Yes	☐ No

g. Identify the distance of the bloom from the drinking-water intake: ______________

h. List any known approved or unapproved recreational use for the source, or if there is a public beach nearby that may be impacted by diverted water from the reservoir:

____

Massachusetts Department of Environmental Protection
Bureau of Water Resources – Drinking Water Program

PWS Bloom Tracking Form

C. Treatment Facility Operation

IMPORTANT: **Note 3:** Treatment for cyanotoxins vary depending upon whether toxins are intracellular or extracellular. PWSs should be aware of their treatment capabilities and update their ERP to include response to a CyanoHAB event.

1. Identify any observed odor(s) in the raw water within the plant:

   ☐ None ☐ Earthy/musty ☐ Fishy ☐ Other

   Other odor (please describe)

2. Increase in the raw water pH: ☐ Yes ☐ No If yes, specify changes:

3. Increase in the filter **influent** turbidity: ☐ Yes ☐ No
4. Increase in the filter **effluent** turbidity: ☐ Yes ☐ No
5. Identify if there are increased filter run times: ☐ Yes ☐ No

   If yes, identify specific run time changes:

6. Increased need for coagulant dosage: ☐ Yes ☐ No
7. Increase in chlorine demand: ☐ Yes ☐ No
8. Decreased chlorine residual at the finished water tap: ☐ Yes ☐ No
9. Any customer complaints about taste and odor: ☐ Yes ☐ No

   If yes, please explain

D. Sampling Information

1. **List any sampling performed within source water for algal identification and enumeration** (or attach lab results):

   Sample Location(s) Sample Date

   Sample type: ☐ Surface grab ☐ Discrete depth ☐ Integrated tube

   Sample depth(s) if applicable:

   Analysis lab name Sample result(s)

IMPORTANT: **Note 4: Sampling** Cyanotoxin sampling should be performed in consultation with your MassDEP regional office.

2. **List any cyanotoxin samples collected and analyzed** (or attach lab results):

   Sample location(s) Sample Date

   Sample location ID (LOCID) if within plant (e.g.., RW-01S)

   Cyanotoxin type: ☐ Microcystins ☐ Cylindrospermopsin ☐ Other:

   Describe other

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PWS Bloom Tracking Form

D. Sampling Information (Cont'd)

Analysis Type: ☐ Strip Test ☐ ELISA (EPA 546) ☐ LC/MS/MS (EPA 545)

Analysis lab name ________ Sample result(s) ________

3. List any additional source water sampling performed:

a. Phycocyanin (PC): ☐ Yes ☐ No ________ Location(s)

________ PC date(s) & result(s)

b. Chlorophyll a: ☐ Yes ☐ No ________ Location(s)

________ Chlorophyll a date(s) & result(s)

c. Secchi Disk Depth (SD): ☐ Yes ☐ No ________ Location(s)

________ SD date(s) & result(s)

d. Water temperature: ☐ Yes ☐ No ________ Location(s)

________ Temperature date(s) & result(s)

e. pH: ☐ Yes ☐ No ________ Location(s)

________ Temperature date(s) & result(s)

f. Dissolved Oxygen (DO): ☐ Yes ☐ No ________ Location(s)

________ DO date(s) & result(s)

g. Total Phosphorus Concentration: ☐ Yes ☐ No ________ Location(s)

________ TP date(s) & result(s)

h. Total Nitrogen Concentration: ☐ Yes ☐ No ________ Location(s)

________ TN date & result

.

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PWS Bloom Tracking Form

E. Ongoing Event Information

Use this section to track any changes observed (e.g., weather changes and bloom movement) or additional monitoring performed for the same event over various hours, days, or weeks.

Date | Time | Operator/staff name

Observations/monitoring conducted

Planned action(s)/next step(s)

Date | Time | Operator/staff name

Observations/monitoring conducted

Planned action(s)/next step(s)

Date | Time | Operator/staff name

Observations/monitoring conducted

Planned action(s)/next step(s)

Date | Time | Operator/staff name

Observations/monitoring conducted

Planned action(s)/next step(s)

Date | Time | Operator/staff name

Observations/monitoring conducted

Planned action(s)/next step(s)

Appendix D

Field Sheet

Lake and Reservoir Field Sheet

Lake/Reservoir Name:	
Station Name	
Date Sampled:	
Time Sampled:	
Site Depth:	
Secchi Transparency (m):	
pH (from core):	
Phycocyanin (0-3m core)	
Chlorophyll a (0-3m core))	
PC/Chlor ratio	
Turbidity (NTU)	
Weather comments:	
Monitors:	

Depth	Temperature	Dissolved Oxygen	Conductivity	Specific Conductance
M	°C	mg/l	µS/cm	µS/cm
0				
0.5				
1				
1.5				
2				
2.5				
3				
3.5				
4				
4.5				
5				
5.5				
6				
6.5				
7				
7.5				
8				
8.5				

Appendix E

Chain of Custody Form

CHAIN OF CUSTODY RECORD

STANDARD

Page __1__ Of __1__

CLIENT NAME:	PROJECT:	ANALYSES REQUESTED	SPECIAL HANDLING
ADDRESS:	PHONE:		☐ Same Day Rush 150%
	FAX:		☐ 24 Hour Rush 100%
	EMAIL:		☐ 48-72 Hour Rush 75%
PROJECT MANAGER	SAMPLER		☐ 4 - 5 Day Rush 30%
			☐ Rush Extractions 50%
			☐ 10 - 15 Business Days
			☐ QA/QC Data Package
			Charges will apply for weekends/holidays
			Method of Shipment

ID# (For lab Use Only)	DATE SAMPLED	TIME SAMPLED	SMPL TYPE	SAMPLE IDENTIFICATION/SITE LOCATION	# OF CONT.											COMMENTS

RELINQUISHED BY	DATE / TIME	RECEIVED BY	SAMPLE CONDITION:		SAMPLE TYPE CODE:
					AQ=Aqueous
			Actual Temperature:		NA= Non Aqueous
					SL = Sludge
RELINQUISHED BY	DATE / TIME	RECEIVED BY	Received On Ice	Y / N	DW = Drinking Water
			Preserved	Y / N	WW = Waste Water
			Evidence Seals Present	Y / N	RW = Rain Water
			Container Attacked	Y / N	GW = Ground Water
RELINQUISHED BY	DATE / TIME	RECEIVED BY	Preserved at Lab	Y / N	SO = Soil
					SD = Sediment
					OL = Oil
					OT = Other Matrix

SPECIAL REQUIREMENTS / BILLING INFORMATION

COC version 042707

APPENDIX F

DRAFT BYLAW TO AMEND THE ZONING BYLAW OF THE TOWN OF WEST NEWBURY – FOR DISCUSSION PURPOSES

Amend the Zoning By-law of the Town of West Newbury, by inserting in its entirety the following Section XX (to be determined – 13?). Surface Water Supply Protection Overlay District.

SECTION XX. SURFACE WATER SUPPLY PROTECTION DISTRICT

XX-A. PURPOSE OF DISTRICT

The purpose of this Surface Water Supply Protection District is:

1. To preserve and protect existing and potential watersheds and aquifers for drinking water supplies.
2. To prevent temporary and permanent contamination in the Surface Water Supply Protection District.
3. To protect the community from the detrimental use and development of land and water within the Surface Water Supply Protection District.
4. To promote the health, safety, and general welfare of the community by protecting and preserving the surface water resources of the Town and region from any use of land or buildings which may reduce the quality of its water resources.

XX-B. SCOPE OF AUTHORITY

The Surface Water Supply Protection District is an overlay district and shall be superimposed over any other district established by this By-law. All regulations of the Town of West Newbury Zoning By-law applicable to such underlying districts shall remain in effect, except where the Surface Water Supply Protection District imposes more restrictive regulations, such regulations shall prevail.

XX-C. DEFINITIONS

For the purpose of this section, the following words and phrases shall have the following meanings:

Aquifer:	Geologic formation composed of rock, sand, or gravel that contains significant amounts of potentially recoverable water.
Disposal:	The deposit, injection, dumping, spilling, leaking, incineration, discharge, or placing of any material into or on any land or surface water or groundwater so that such material or any constituents thereof may enter the environment or be emitted into the air or discharged into any waters subject to this bylaw.
Disturbance:	Activities including, but not limited to, land clearing and grading, tree and shrub removal, mowing, burning, spraying, grazing, soil and gravel removal, all construction, and any other unlawful or disruptive activities.
Groundwater:	All water beneath the surface of the ground in a saturated zone.

Impervious:	Material or structure on, above, or below the ground that does not allow precipitation or surface water to penetrate directly into the soil.
Mining:	The removal or relocation of geological materials such as topsoil, sand, gravel, metallic ores, or bedrock.
Recharge Areas:	Areas that collect precipitation or surface water and transmit it to aquifers.
Surface Water:	All water open to the atmosphere and subject to surface runoff, including, but not limited to, rivers, streams, lakes, ponds, springs, impoundments, estuaries, wetlands, coastal waters, and vernal pools.
Surface Water Supply Protection District:	The zoning district defined to overlay other zoning districts in the Town, consisting of three distinct watershed zones for surface water sources: Zone A, Zone B, and Zone C
Toxic or Hazardous Material:	Any substance or mixture of substances which, because of its physical, chemical, or infectious characteristics, posing a significant actual or potential hazard to water supply or to human health if such substance or mixture were discharged to land or water of the Town. Toxic or hazardous materials include, without limitation, synthetic organic chemicals, petroleum products, heavy metals, radioactive or infectious wastes, acids and alkalis, and all substances defined as Toxic or Hazardous under Massachusetts General Laws (MGL) Chapter 21C and 21E and 310 CMR 30.00 as well as such products as solvents and thinners in quantities greater than those associated with normal household use.
Tributary:	Any body of running , or intermittently running, water that moves in a definite channel, naturally or artificially created, in the ground due to a hydraulic gradient, and that ultimately flows into a Class A surface water source, as defined in 314 CMR 4.05 (3) (a).
Watershed:	Land area bounded by a ridgeline of higher elevation, or drainage divide, from which surface runoff and groundwater flow downgradient into streams, ponds, reservoirs, wetlands, and aquifers. An aquifer is located within a watershed and is recharged by precipitations falling on watershed land.
Watershed Zones:	The Watershed Zones are generally defined by the direction of the flow of water. These zones are specifically shown on the delineation map identified in Section XX-D of this bylaw, and are described as follows:
Zone A:	(a) The land area between the surface water source and the upper boundary of the bank; (b) the land area within a 400-foot lateral distance from the upper boundary of the bank of a Class A surface water source, as defined in 314 CMR 4.05 (3) (a); and (c) the land area within a

200-foot lateral distance from the upper boundary of the bank of a tributary or associated surface water body.

Zone B: The land area within one-half mile of the upper boundary of the bank of a Class A surface water source, as defined in 314 CMR 4.05 (3) (a), or edge of the watershed, whichever is less. However, Zone B shall always include the land area within a 400-foot lateral distance from the upper boundary of the bank of the Class A surface water source.

Zone C: The land area not designated as Zone A or Zone B within the watershed of a Class A surface water source, as defined in 314 CMR 4.05 (3) (a).

XX-D. ESTABLISHMENT AND DELINEATION OF A SURFACE WATER SUPPLY PROTECTION DISTRICT

This bylaw establishes within the Town of West Newbury certain water resource protection zones, consisting of watershed areas of the Indian Hill Reservoir, Upper Artichoke Reservoir, and Lower Artichoke Reservoir, which are delineated on a map entitled "Surface Water Supply Protection District, Town of West Newbury" dated XXX. This map is hereby made part of the Town Zoning By-law and is on file in the Office of the Town Clerk and the Office of the Planning Board.

Where the boundary of the Surface Water Supply Protection District divides any lot existing at the time such line is established, the regulations established hereunder shall not apply to the portion of such lot not located with the Water Supply Protection District, provided such lot does not extend more than 25 feet into the Surface Water Supply Protection District.

If the location of the District boundary in relation to a particular parcel is in doubt, resolution of boundary disputes shall be through a Special Permit application to the Special Permit Granting Authority (SPGA). Any application for a special permit for this purpose shall be accompanied by adequate documentation. The burden of proof shall be upon the owner(s) of the land to show where the bounds should be located. At the request of the owner(s), the Town may engage a professional civil or sanitary engineer, hydrologist, geologist, or soil scientist to determine more accurately the boundaries of the district with respect to individual parcels of land, and may charge the owner(s) for the cost of the investigation.

XX-E. ALLOWED USES WITHIN THE SURFACE WATER SUPPLY PROTECTION DISTRICT

Water supply related activities will not be subject to regulations within this bylaw.

The following uses are allowed within the Surface Water Supply Protection District, provided that all necessary permits, orders, or approvals required by local, state, or federal law are first obtained:

1. Conservation of soil, water, plants, and wildlife.
2. Outdoor recreation, nature study, boating, fishing, and hunting where legally permitted, subject to Section XX-F, G, and H (Prohibited Uses) and Section XX-I (Special Permitted Uses).
3. Foot and/or bicycle paths and associated bridges
4. Normal operation and maintenance of existing water bodies and dams, splashboards, and other water control, supply, and conservation devices.

5. Maintenance, repairs, and enlargement of any existing structure, subject to Sections XX-F, G, and H (Prohibited Uses) and Section XX-I (Special Permitted Uses).
6. Residential development, subject to Sections XX-F, G, and H (Prohibited Uses) and Section XX-I (Special Permitted Uses).
7. Farming, gardening, nursery, conservation, harvesting, and grazing, subject to Sections XX-F, G, and H (Prohibited Uses) and Section XX-I (Special Permitted Uses).
8. Construction, maintenance, repair, and enlargement of drinking water supply related facilities such as, but not limited to, wells, pipelines, aqueducts, and tunnels. Underground storage tanks related to these activities are not categorically allowed.

XX-F. PROHIBITED USES WITHIN ALL THREE ZONES OF THE SURFACE WATER SUPPLY PROTECTION DISTRICT

No use variance shall be granted so as to permit any of the uses prohibited by the foregoing section.

1. Landfills and open dumps as defined in 310 CMR 19.006.
2. Landfilling of sludge or septage as defined in 310 CMR 32.05.
3. Storage of sludge and septage, unless such storage complies with 310 CMR.32.30 and 310 CMR 32.32.
4. Automobile graveyards and junkyards, as defined in MGL c. 140B, s.1.
5. Storage of liquid hazardous materials, as defined in MGL c. 21E, unless in free standing containers within a building or above ground with secondary containment adequate to contain a spill 110% the size of the container's total storage capacity.
6. Stockpiling and disposal of snow and ice containing deicing chemicals as well as disposal of such material directly into a tributary to the principal water supply.
7. Placement of fill, unless the fill has been designated as "clean fill".
8. Storage of deicing chemicals, unless such storage (including loading areas) is within a structure designed to prevent the generation and escape of contaminated runoff or leachate.
9. Any other activity deemed likely to cause or contribute to the contamination of the public water supply.
10. No water shall be diverted out of the Surface Water Supply Protection District.

XX-G. ADDITIONAL PROHIBITED USES WITHIN ZONE A & B

1. Individual sewage disposal systems that are designed and located in accordance with 310 CMR 15.000 to receive more than 110 gallons of sewage per quarter acre under one ownership per day, or 440 gallons of sewage on any acre under one ownership per day, whichever is greater, except the replacement or repair of an existing system that will not result in design capacity above the original design.
2. Storage of animal manure unless covered or contained to prevent the generation and escape of contaminated runoff or leachate.
3. Earth removal, consisting of the removal of soil, loam, sand, gravel, or any other earth material (including mining activities) to within 6 feet of historical high groundwater as determined from monitoring wells and historical water table fluctuation data compiled by the United States Geological Survey, except for excavations for building foundations, roads, or utility works.

4. Facilities that generate, treat, store, or dispose of hazardous waste subject to MGL 21C and 310 CMR 30.00, except the following:
    a. Waste oil retention facilities required by MGL C21, s 52A.
    b. Water remediation treatment works approved under 314 CMR 5.00.
5. Treatment works that are subject to 314 CMR 5.00, including privately owned sewage treatment facilities, except the following:
    a. Replacement or repair of an existing treatment works that will not result in a design capacity greater than the design capacity of the existing treatment works.
    b. Replacement of existing subsurface sewage disposal system(s) with waste treatment works that will not result in a design capacity greater than the design capacity of the existing sewage disposal system(s).
    c. Treatment works designed for the treatment of contaminated surface water and groundwater, approved by the Massachusetts Department of Environmental Protection.
6. Industrial and commercial uses that discharge process wastewater on site.
7. Alteration of any bordering vegetated wetland.
8. Incinerators.
9. Above ground storage of liquid hazardous materials as defined in MGL Chapter 21E, or liquid propane or liquid petroleum products, except the following:
    a. Normal household use, outdoor maintenance, and heating of a structure.
    b. Waste oil retention facilities required by statute, rule, or regulation.
    c. Emergency generators required by state regulations.
    d. Treatment works approved under 314 CMR 5.00 for treatment of ground or surface waters.

    Provided that such storage, listed in items a. through d. above, is in free-standing containers within buildings or above ground with secondary containment adequate to contain a spill the size of 110% of the container's total storage capacity.

10. Commercial repair, servicing, washing, and rebuilding of vehicles, boats, and other large motorized equipment other than for normal household or farming activities.
11. Storage of commercial fertilizers, as defined in MGL Chapter 128, section 64, unless such storage is within a structure designed to prevent the generation and escape of contaminated runoff and leachate.

XX-H. ADDITIONAL PROHIBITED USES WITHIN ZONE A

1. All underground storage tanks.
2. Construction or placement of any permanent structures, other than those associated with flood control or water supply.
3. Any surface or subsurface discharge, including, but not limited to, stormwater or hazardous materials, except as allowed by special permit.
4. Wading, swimming, bathing, or boating in the municipal water supply or its tributaries.
5. New or expansion of existing horse paths.
6. Construction of new roads.
7. All sewer lines and appurtenances, except as required to eliminate existing or potential pollution to the water supply, or where the crossing of tributaries is necessary to construct a public sewer

Commented [TJA1]: Highlighted items may be better in a BOH regulations system. Where the exception is met, watertight construction of sewer lines and manholes shall be used.

8. Any burial place or cemetery within 100 feet of the high-water mark of a tributary.
9. Stabling, hitching, standing, feeding or grazing of livestock or other domestic animals within 100 feet of the bank of a surface water source or tributary thereto.
10. Storage of animal manure, even if covered and contained.
11. Facilities that generate, treat, store, or dispose of hazardous waste subject to MGL 21C and 310 CMR. 30.00, regardless of size and quantity of hazardous waste generated.
12. Snowmobiling, dirt biking, all-terrain vehicles (ATVs), sea planes, and any other activities that in the opinion of the Special Permit Granting Authority (SPGA) presents a threat to the water supply or the watershed.

XX-I. USES REQUIRING A SPECIAL PERMIT WITHIN ALL THREE ZONES OF THE SURFACE WATER SUPPLY PROTECTION DISTRICT

The following uses and activities are allowed only upon the issuance of a Special Permit by the Special Permit Granting Authority (SPGA) under such conditions as the SPGA may require.

1. Enlargement or alterations of existing uses that do not conform to the Surface Water Supply Protection District.
2. Application of pesticides, herbicides, insecticides, fungicides, and rodenticides for non-domestic or non-agricultural uses in accordance with the state and federal standards. The special permit shall be granted if standards are met. If applicable, the application shall provide documentation of compliance with a Yearly Operating Plan (YOP) for vegetation management operations under 333 CMR 11.00 or a Department of Food and Agriculture approved Pesticide Management Plan or Integrated Pest Management (IPM) program under 333 CMR 12.00.
3. Application of fertilizer for non-domestic or non-agriculture uses. Such application shall be made to minimize adverse impacts to surface water and groundwater quality due to nutrient transport, deposition, and sedimentation.
4. Activities that involve the handling of toxic or hazardous materials in quantities greater than those associated with normal household use, if allowed in the underlying zoning (except as prohibited under Section XX-H, I, and J). Such activities shall require a special permit to prevent contamination of surface water and groundwater.
5. Construction of dams or other control devices, ponds or other changes in the waterbodies or courses, created for swimming, fishing, or other recreational uses, agricultural uses, or drainage improvements. Such activities shall not adversely affect water quality or quantity.
6. Any land uses that result in the rendering impervious of more than 15% or 2500 square feet of any lot or parcel, whichever is greater. A system for groundwater recharge shall be provided which does not degrade ground or surface water quality. For all non-residential uses, recharge shall be by stormwater infiltration basins or similar systems covered with natural vegetation. Dry wells shall be use only where other methods are infeasible. For all non-residential uses, all such infiltration basins and dry wells shall be preceded by oil, grease, and/or sediment traps to facilitate removal of contaminants. All recharge areas shall be regularly maintained in proper working order by the owner.

7. Residential construction upon a lot with an average slop exceeding 15%. An acceptable plan for site stabilization and control of erosion and sedimentation shall be provided.
8. Any new stormwater runoff shall be set back from the receiving water a minimum of 100 feet and shall include best management practices appropriate to the site. Stormwater management best management practices shall be optimized for nitrogen and phosphorus removal. Existing and replacement discharges shall be set back from the receiving water when either then site stormwater drainage system is changed, or the discharge is increased. The best management practices shall be designed to maximize infiltration and minimize erosion and to mitigate water quality impacts, including those due to total suspended solids and oil and grease. This applies to stormwater runoff from all impervious surfaces, including roads and parking lots.

XX-J. PROCEDURES FOR ISSUANCE OF SPECIAL PERMIT

1. The Special Permit Granting Authority (SPGA) under this bylaw shall be the Planning Board. Such special permit may be granted if the SPGA determines, in conjunction with the Board of Water Commission (both West Newbury and Newburyport), Board of Health, Conservation Commission, and Department of Public Works that the intent of thus bylaw, as well as specific criteria, are met. The SPGA shall not grant a special permit under this section unless the petitioner's application materials include, in the SPGA's opinion, sufficiently detailed, definite, and credible information to support positive findings in relation to the standards given in this section. The SPGA shall document the basis for any departures from the recommendations of the other municipal boards or agencies in its decision.
2. Upon receipt of the special permit application and filing fee, the SPGA shall transmit one copy each to the Board of Water Commission (both West Newbury and Newburyport), Board of Health, Conservation Commission, and the Department of Public Works for their written recommendations. Failure to respond in writing within 60 days of receipt shall indicate approval or no desire to omit by said agency. The requisite number of application copies shall be furnished by the applicant.
3. The SPGA may grant the required special permit only upon finding that the proposed use meets the requirements specified in Sections XX-E, F, G, H, and I of this bylaw, any regulations or guidelines adopted by the SPGA, and the following standards. The proposed use must:
   a. In no way adversely affect the existing or potential quality or quantity of water that is available for on-site recharge in the Surface Water Supply Protection District during or after construction.
   b. Be designed to avoid substantial disturbance of the soils, topography, drainage, vegetation, and other water related natural characteristics of the site to be developed, in adherence to the practices outlines in "Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas". (USDA Natural Resources Conservation Service, Franklin, Hampden, Hampshire Conservation Districts, March 1997, Reprint May 2003).
4. The SPGA may adopt regulations to govern design features of projects.
5. The applicant for a special permit shall file eleven (11) copies of a site plan and attachments. The site plan shall be drawn at a proper scale and be stamped by a professional engineer as determined by the SPGA. All additional submittals shall be prepared by qualified professionals.

The site plan and its attachment shall include at a minimum the following information where pertinent:

a. A complete list of chemicals, pesticides, fertilizers, fuels, and other potentially hazardous materials to be used or stored on the premises in quantities greater than those associated with normal household use.
b. For those activities using or storing such hazardous materials, a hazardous materials management plan shall be prepared and filed with the Hazardous Materials Coordinator, Fire Chief, and Board of Health. The plan shall include:
    i. Provision to protect against the discharge of hazardous materials and waste to the environment due to spillage, accidental damage, corrosion, leakage, or vandalism, including spill containment and clean-up procedures.
    ii. Provisions for indoor secured storage of hazardous materials and waste on impervious floor surfaces.
    iii. Evidence of compliance with Regulations of the Massachusetts Hazardous Waste Management Act 310 CMR 30.00, including obtaining an EPA identification number from the Massachusetts Department of Environmental Protection.
c. Proposed downgradient locations for surface water or groundwater monitoring should the SPGA deem the activity a potential surface water or groundwater threat.

6. The SPGA shall hold a public hearing, in conformity with the provision of MGL c. 40A, s.9, within 90 days after the filing of the application and after the review by the appropriate Town Boards, Departments, and Commissions.

   Notice of the public hearing shall be given by publication and posting and by first-class mailing to "parties of interest" as defined in MGL c. 40A, s. 11. The decision of the SPGA and any extension, modification, or renewal thereof shall be filed with the SPGA and Town Clerk within 90 days following the closing of the public hearing. Failure of the SPGA to act within 90 days shall be deemed as a granting of the permit. However, no work shall commence until a certification is recorded as required by MGL Chapter 40A Section 11.

XX-K. ENFORCEMENT

Written notice of any violation of the Bylaw shall be given by the appropriate authority (Code Enforcement Officer, Building Inspector) to the responsible person as soon as possible upon observation, detection, or knowledge or proof that a violation has occurred. Notice to the assessed owner of the property shall be deems notice to the responsible person. Such notice shall specify the requirements or restriction violated and the nature of the violation and may also identify the actions to remove or remedy the violations, preventive measures required for avoiding future violations, and a schedule of compliance. A copy of such notice shall be submitted to the Board of Water Commissioners (both West Newbury and Newburyport), Building Inspector, Board of Health, Conservation Commission, and Department of Public Works. The cost of containment, cleanup, or other action of compliance shall be borne by the assessed owner of the property.

For situations that require remedial action to prevent impact to the water resources within the Surface Water Supply Protection District, the Building Inspector, the Board of Health, or any of their agents may order the owner and/or operator of the premises to remedy the violations. If said owner and/or operator does not comply with said order, the Building Inspector, the Board of Health, or any of their agents, if authorized to enter upon such premises under the terms of the special permit or otherwise, may act to remedy the violation. The cost of remediation shall be the sole responsibility of the owner and/or operator of the premises

XX-L. SEVERABILITY

A determination that any portion or provision of this Surface Water Supply Protection District Bylaw is invalid shall not invalidate any other portion or provision thereof, nor shall it invalidate any special permit issued previously thereunder.

APPENDIX G

Department of Public Services
Newburyport, Massachusetts

Community Outreach Plan

City of Newburyport

June 2021

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Overview

The City of Newburyport's water supply system is primarily sourced by three connected reservoirs: Indian Hill Reservoir, Upper Artichoke Reservoir and Lower Artichoke Reservoir. Newburyport also serves West Newbury and Newbury. The majority of the watershed for the reservoir system is located within West Newbury. Protection of the watershed is of critical importance to protecting the water quality of the reservoir system as exemplified by the algal blooms in the summer of 2020. These blooms are fed in part by nutrients in stormwater runoff from the watershed that buildup within the reservoirs.

As part of the City's watershed protection and management plan, the City will be conducting water sampling at key locations within the watershed to better identify potential sources of nutrients and other pollutants into the reservoirs. In addition, the City of Newburyport is working with West Newbury to implement a Surface Water Supply Protection Bylaw to establish land use protections within the watershed of the reservoir. Both of these activities will require community outreach at various scales. The water quality sampling will be conducted at various locations throughout the City of Newburyport and the Town of West Newbury, some of which will require access across private property. Bylaw amendments will also require outreach to residents of West Newbury, as Zoning amendments require a 2/3 vote at Town Meeting. These endeavors are two actions the City is taking to protect the water quality of its surface water reservoirs that provide drinking water to the region.

Water Quality Outreach

All landowners, residents, farms and users of the public lands within the watershed have the potential to impact the quality of the reservoirs. People are not always aware of how their actions can impact the water supply. Informing the public of key ways that they can help support the protection of the water supply is an important step in watershed management.

Target Audiences

Outreach to landowners, residents, farms and users of the public lands within the watershed is recommended. The City's goal is to provide information on the watershed, the water quality concerns and the steps that the public can take to better protect the watershed and the reservoirs. Target audiences include:

- Essex County Greenbelt Association and recreational users
- Recreational users of Newburyport's watershed lands
- West Newbury residents and property owners within the watershed
- Newbury residents and property owners within the watershed
- Newburyport residents and property owners within the watershed

Communication Options

Communication Method	Purpose	Audience
Direct Mail to Property Owners	Notification letters sent to property owners to inform them of water quality concerns and BMPs they can implement.	• Property owners within watershed
Public Outreach Meetings	Public outreach meeting specific to water quality and watershed protection, including a description of the vulnerability of the water supply and actions the public at large can take to protect the reservoir's water quality	• Town and City officials • Public at Large • Property owners within watershed
Webpage	A summary of the water quality resources will be provided on the City of Newburyport website	• Public at Large • Project Neighbors • Members of the Community
Informational Contact Information	Identify a staff person at the Newburyport Water Department to be available to answer questions about water quality.	• Public at Large • Project Neighbors • Members of the Community
Door Hangers	Provides physical door hanger signs with watershed information and contact information.	• Property owners within watershed
Signage at public properties, including City-owned watershed lands and Essex Greenbelt properties	Provide signage on allowed uses, prohibited uses, and reminders to pick up and properly dispose of pet waste	• Recreational users of watershed lands, including dog walkers and horseback riders
Direct contact through mail/ discussions	If issues are identified that directly impact the reservoir water quality, the City of Newburyport will work with the West Newbury and Newbury Town Managers and Health Agents to make contact with the appropriate landowner to address the situation.	• Property owners

Water Quality Sampling

Water quality sampling within the watershed to the City of Newburyport's reservoirs began in the fall of 2020 and is expected to be ongoing. Sampling will occur at outfalls, drainage ditches, streams, and stormwater management systems throughout the watershed with some of the work requiring access across private properties within West Newbury and Newburyport.

Sampling is non-invasive and entails obtaining access to the stream or stormwater structure to be sampled and collection of water samples from the identified location.

Target Audiences

Outreach leading up to and throughout water sampling is intended to prepare stakeholders and homeowners for upcoming activities, which will be taking place at various locations within the watershed. The City's goal is to provide accurate timelines, potential impacts and means of contact directly with the City. Target audiences in West Newbury include:

- Town Manager, Police Chief, Water Department and DPW
- West Newbury residents (specifically property owners within the sampling vicinity)

The City's outreach goals are to ensure that staff promptly notifies, responds to, documents, and resolves sampling-related concerns from stakeholders related to the project. Anticipated concerns may consist of:

- Private Property Crossing – Sampling activities are not expected to disrupt private property. The City will continue to proactively update landowners of activities occurring on their property.
- Sampling Results – The City intends to use the sampling results to inform decision making on where to best direct watershed improvement projects.

Water Quality Sampling Communications

The City of Newburyport will communicate water quality sampling information through multiple methods tailored to the diverse stakeholder audiences. All communications will guide stakeholders to the City's contact for the most commonly requested information. The following is a list of communication methods available to project stakeholders:

Communication Method	Purpose	Audience
Direct Mail to Property Owners	Notification letters will be sent to property owners prior to collecting samples near or on their property.	• Property owners directly impacted by sampling
Email Notifications	The City of Newburyport will notify key officials in West Newbury regarding when and where water sampling is proposed to take place. Town officials will be provided with contact names for who will be conducting the sampling and who should be contacted for questions.	• West Newbury municipal staff: Town Manager, Police Chief, Water Department
Webpage	A summary of the water quality sampling will be provided on the City of Newburyport website.	• Public at Large • Project Neighbors • Members of the Community
Informational Contact Information	The Newburyport Water Department will be available to answer questions about the water quality sampling. Correspondence through the Water Department will be logged and archived. Contact: TBD Email: TBD	• Public at Large • Project Neighbors • Members of the Community

	Phone: TBD	
Door Hangers (optional)	Provides physical door hanger signs with project information and contact information.	• Project Neighbors
Direct contact through mail/ discussions	If issues are identified that directly impact the reservoir water quality, the City of Newburyport will work with the West Newbury Town Manager and Health Agent to make contact with the appropriate landowner to address the situation.	• Property owners

Bylaw Development

A draft bylaw has been developed for discussion purposes with key stakeholders in the Town of West Newbury including the Water Commission, Water Department, Town Manager, Selectboard, Planning Board and Board of Health. Newburyport's goal is for the bylaw to be on the warrant at a future West Newbury Town Meeting.

Bylaw Development Communications

Currently the bylaw is drafted as an amendment to the Zoning Bylaw. As such, the bylaw will require a Planning Board hearing (within 6 months of the Town Meeting), and Town Meeting approval. Additional stakeholders include the West Newbury Water Department and Water Commission, Town Manager and property owners within the watershed. The City of Newburyport will conduct outreach through multiple methods noted below. All communications will guide stakeholders to the City's contact and project webpage for the most commonly requested information. The following is a list of communication methods available to project stakeholders:

Communication Method	Purpose	Audience
Webpage	Project webpage will provide a copy of the draft bylaw language and overview, including the importance of enacting the bylaw.	• Public at Large • Members of the Community
Informational Contact Information	The Newburyport Water Department will be available to answer questions about the proposed bylaw. Correspondence through the Water Department will be logged and archived. Contact: TBD Email: TBD Phone: TBD	• Public at Large • Members of the Community
Informational meetings	The City of Newburyport will meet with key West Newbury municipal stakeholders to discuss the proposed bylaw and to seek input for incorporation into the draft. The City of Newburyport anticipates meeting with: • Town Manager • Water Department Superintendent	• Key Town departments/ boards

	• Board of Water Commissioners • Health Agent • Town Planner	
Public Meeting/Hearing	Public meetings/hearings will be held to discuss bylaw development. Information on public meeting/hearings will be posted on the webpage. Anticipated meetings include: • Board of Water Commissioners Meeting • Planning Board Hearing • Town Meeting	• Key Town boards • Members of the Community

Summary

The City of Newburyport is committed to working with the Town of West Newbury to protect the shared resource of the drinking water reservoir system. As other stakeholders are identified, they will be included in the outreach efforts.

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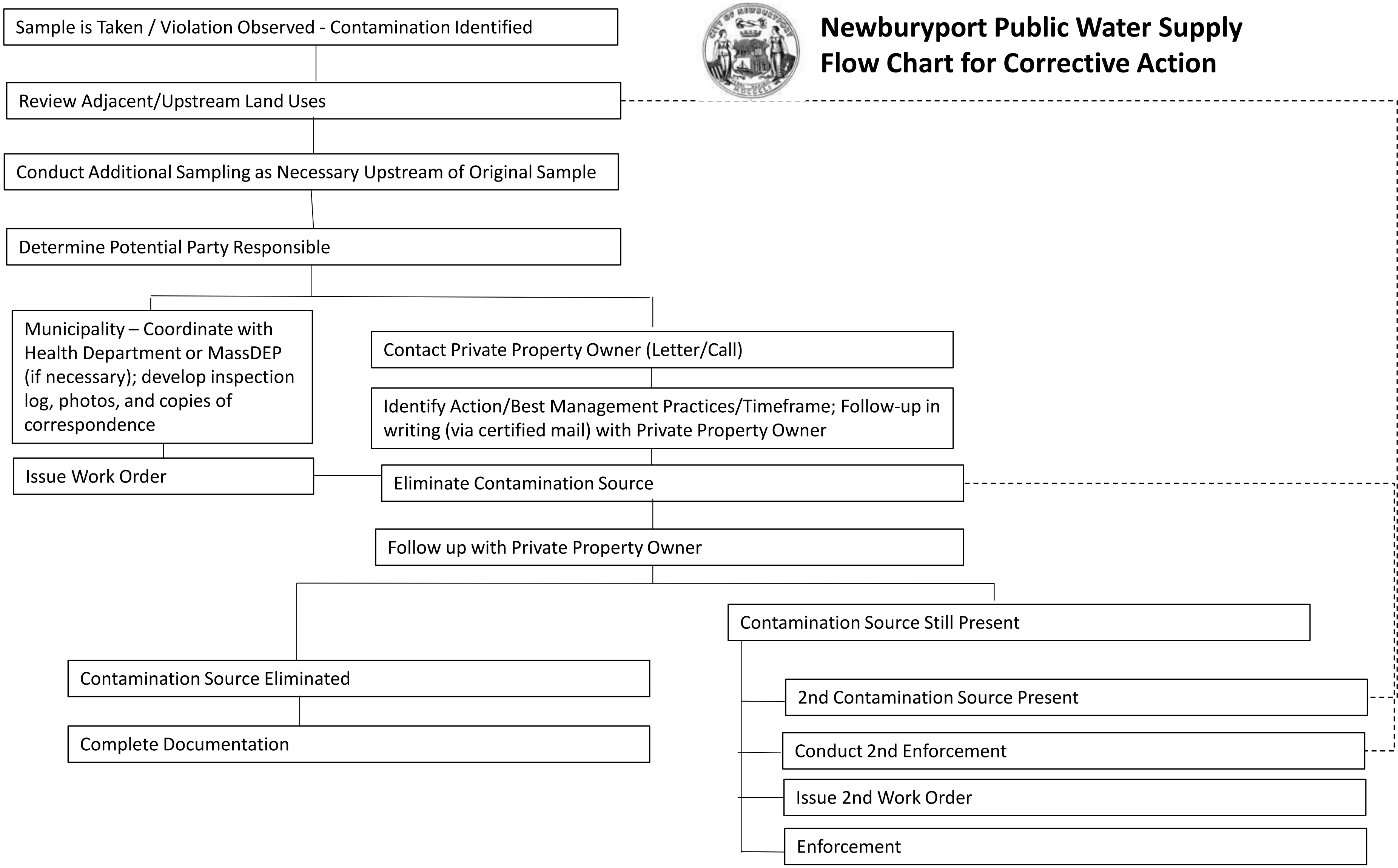
APPENDIX H

Newburyport Public Water Supply
Flow Chart for Corrective Action



Massachusetts Department of Environmental Protection
REGULATORY IMPROVEMENTS FOR RESERVOIRS

Enforcement of 310 CMR 22.20B

The Massachusetts Drinking Water Regulations set forth in 310 CMR 22.20B land use prohibitions and controls within certain distances from all public drinking water reservoirs. Most of the provisions were written in the 1930s and, until recently, did not adequately reflect current source protection issues. With the help of suppliers and others, this section was updated, effective January 5, 2001, to address that gap in protection. Many communities also have more stringent controls in place in the form of local watershed protection bylaws, ordinances or regulations, and suppliers may own or control significant portions of their watersheds.

Although DEP may take enforcement actions against any persons violating 310 CMR 22.20B, public water suppliers have always been the primary enforcers of these land use controls. Section 22.20B(7)(a) requires the following:

- a public water system shall conduct regular and thorough inspections of Zones A, B and C to determine and enforce compliance with 310 CMR 22.20B; and

- the public water system shall take prompt enforcement actions against persons violating 310 CMR 22.20B and shall report all such enforcement actions and the results of the regular inspections made during the preceding calendar year to the Department in the system's Annual Statistical Report. The report shall include the number and dates of the inspections, the number, nature and outcome of violations found and enforced against by the public water system and the general condition of the watershed at the time of the last inspection.

Regular inspections of the watershed not only help suppliers meet these requirements, but also allow them to keep up with changes in the watershed, especially where the reservoir and/or watershed lands extend into other communities. In addition, inspections can provide information for more effective planning for land acquisition, emergency response, public education and other source protection measures.

Enforcement Steps

Except in the case of an immediate public health threat, a visit or call to the owner(s) of the affected property with a request for cooperation and compliance, with specific actions to be performed and dates by which to perform them, should be the first step in an enforcement case. A follow-up letter, confirming the details of the conversation, should be sent to the owner(s) by certified mail (with a copy to the system's legal counsel). An inspection log, photographs and copies of all correspondence should be assembled for each enforcement case.

If the owner is not cooperative and does not follow through with the actions and timetable set forth by the supplier (and does not request a reasonable revision of the schedule), it may be necessary to involve the system's legal counsel in pursuing a more formal enforcement action.

Enforcement Authority

The scope and nature of a public water supplier's enforcement authority depends, in large part, on the status of the supplier - e.g., whether it is a municipal water system or a private entity acting as a public water system. Accordingly, suppliers should consult with their legal counsel to ensure that any relevant bylaw, ordinance or penalty provision is properly enacted and enforceable, and that specific compliance and enforcement activities and actions that a supplier may undertake are within the scope of their authority. With that cautionary note in mind, the Department has the following guidance.

- Under M.G.L. c. 40, s.21, municipalities have broad authority to adopt ordinances and bylaws, including for the regulation of the use of reservoirs connected with its water supply and "land and driveways appurtenant thereto." At present, M.G.L. c. 40, s.21 provides for a penalty not exceeding $50 for each violation of a "use of reservoir" bylaw authorized under subsection (8), which are recovered by a municipality on complaint before a district court or by non-criminal disposition in accordance with M.G.L. c. 40, s.21D.

- Water boards or boards of water commissioners of municipalities or water districts, any executive officer or agent of such board or of a public institution or water company, and any police officer employed by such suppliers, have the authority to enter any premises, excluding dwelling houses, within the watershed of a public water supply source to determine compliance with the requirements of 310 CMR 22.00. See M.G.L. c. 111, s.173B. In addition, police officers employed by the above referenced suppliers have all the powers and duties of municipal police officers in the cities and towns served by the supplier. See M.G.L. c. 111, s.173A.

- An independent water commission, established pursuant to M.G.L. c. 40N, is authorized to adopt rules and regulations in connection with the performance of its functions and to enforce and collect penalties for violation of its regulations. Such commission also has the authority to enter lands within the commission's service area for inspection purposes.

- Finally, private water districts and other private entities that act as public water systems must rely on other sources of authority to regulate and enforce against land uses consistent with 310 CMR 22.20B (e.g., special legislation, the terms of its contract with users). In addition, non-municipal suppliers should use their best efforts to request the relevant municipality to use its zoning and other regulatory authority, including ordinances and bylaws established pursuant to M.G.L. c. 40, s.21(8), to implement and enforce the land use prohibitions in 310 CMR 22.20B.

Enforcement Examples

Swimming in drinking water reservoirs is prohibited by 310 CMR 22.20B. The Board of Water & Sewer Commissioners in Town A posted drinking water signs indicating "no swimming" and conducted regular inspections of the reservoir. The Water Superintendent found that swimming was occurring. The town had a bylaw regulating the use of the reservoir and, under authority from MGL Chapter 40, section 21, the Commissioners voted to fine swimmers $50 for repeat violations (i.e. persons identified swimming a second time). They also decided to issue a press release explaining the Commission's need to take such action; increase inspections at the reservoir during the summer; and expand their public education program.

Water District B's watershed extends into another community that does not receive water from that reservoir. Responding to a complaint, the Water Superintendent observed that a new underground storage tank was being installed within Zone A at a facility in the other community in violation of 310 CMR 22.20B. While talking with the Building Inspector (the zoning enforcement officer) in the other community, the Water Superintendent learned that the tank was also being installed in violation of that community's ground water protection zoning bylaw. The Building Inspector, who had been unaware of the violation, spoke with the facility owner. The owner was not cooperative and continued with the installation. The Building Inspector offered to take the lead on pursuing enforcement in this matter and to keep the District informed of any actions related to the case. The Water District spoke with their legal counsel and retained the option of pursuing the case in the future if necessary.

Water Company C observed that a resident had established two horses in his backyard between 60 ft. and 200 ft. of the bank of a tributary to the Company's reservoir. Keeping horses within 100 ft. of a tributary is a violation of 310 CMR 22.20B. Under the authority of the terms of the contracts with the users of the water, the supplier met with the resident, explained the violation and outlined the steps that the resident needed to take to come into compliance. The resident agreed to move the horses back 40 ft. (outside Zone A) and to allow the vegetation that had been altered within Zone A to grow back. As a follow-up to the meeting, the supplier sent a letter, by certified mail, to the resident describing the violation, outlining the agreed-upon resolution and thanking him for his cooperation. She also included, with the letter, copies of DEP's fact sheet on manure management and other fact sheets related to backyard horses within drinking water supply areas. Through re-inspection, the supplier confirmed compliance with her orders.

Massachusetts Watersheds That Extend Into Other States

Massachusetts regulations cannot be enforced in other states. Suppliers with watersheds that extend into another state should maintain contact with local officials in the other state, review and comment on relevant new projects in the watershed and conduct public education about protection measures.

Contact Kathy Romero, Drinking Water Program, 617-292-5727
This information is available in alternate format by calling DEP's ADA Coordinator at 617-574-6872.

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101 Arch Street, 12th Floor, Boston, MA 02110

TO: Jon-Eric White
Anthony Furnari
Jamie Tuccolo
Thomas Cusick
Diane Gagnon

FROM: Amy E. Kwesell, Esq.

RE: Public Water Supply (Surface Water) and Water Rights

DATE: August 19, 2020

In response to possible contamination to one of the City's public water supplies ("PWS"), enforcement options are outlined below.

BACKGROUND:

A dairy farmer has been allowing his cows to bathe in the reservoir serving as a City water supply, creating run-off and contamination concerns. Additionally, while the land beneath most of the reservoirs and the reservoirs themselves are owned by the City, most of the land surrounding the reservoirs, including the farm at issue, is in West Newbury.

I have reviewed the following:

- Chapter 403 of the Acts of 1908;
- Agreement between City of Newburyport and Town of West Newbury dated March 10, 1980;
- WMA Permit #9P231332401 dated May 30, 2017;
- Prior enforcement attempts with Artichoke Farm;
- Documents related to the contamination of Bartlett Spring Pond by Arrowhead Farm;
- Powers of Cities and Towns, Public Water Supply statutes, G.L. c. 40, §§ 39A – 39G;
- Massachusetts Drinking Water Regulations, 310 CMR 22.00;
- Public Health statutes, G.L. c. 111, § 162;
- Wetland Protect Act, G.L. c. 131, § 40; and
- Federal Clean Water Act Section 404.

ENFORCEMENT OPTIONS:

The most feasible causes of action, in my opinion, may be undertaken pursuant to G.L. c. 40, § 39G and G.L. c. 111, § 167. Below, please find a summary of enforcement options.

Trespass, Nuisance and Public Water Supply Statutes. Use of these statutes as a basis for enforcement is the recommended course of action at this time. G.L. c. 40, §§ 39A-G governs pollution of public drinking water supplies in towns. As there is no equivalent provision for cities, it likely would apply to the City of Newburyport as well. See G.L. c. 40, § 1 ("cities shall have all the powers of towns [under this Chapter]…, and all laws relative to towns shall apply to cities"). Section 39G of Chapter 40 provides: "[w]hoever wilfully or wantonly corrupts, pollutes or diverts any of the waters taken or held under said sections thirty-nine A to thirty-nine E [public drinking water supply, including reservoirs], inclusive, or injures any structure, work or other property owned, held or used by a town under the authority and for the purposes of said sections, shall forfeit and pay to said town three times the amount of damages assessed therefor, to be recovered in an action of tort…."

Here, then, the City could bring a tort action for property damage against the farmer or property owner for treble damages. Cf. Town of Sturbridge v. Mobil Corp., 195 F. Supp. 2d 330, 332 (D. Mass. 2002) ("Town brought suit against Mobil, Shell, and ARCO in Worcester Superior Court alleging property damage pursuant to M.G.L. c. 40 § 39G"). The action should be instituted by the Board of Water and Sewer Commissioners (who manage and control drinking water and land under G.L. c. 40, § 39E) or by the Mayor. Before doing so, we recommend that the City send a demand letter to the farmer outlining the violation and requesting that the farmer take appropriate action. The City may wish to hire a consultant to evaluate the contamination and possible damages before instituting an action for treble damages.

The only recent court to analyze this statute has held that "[n]o person has a legal right to impair to an unreasonable extent the quality of a water supply shared with others." Kane v. Town of Hudson, 7 Mass. App. Ct. 556, 561 (1979) (collecting cases). In measuring the extent of the corruption or pollution of public water supplies, the Appeals Court has noted in dicta that "whatever clouding or discoloration would be imparted to the water at the town wellhead by the operation of the plaintiffs' dragline more than 400 feet away would constitute a 'corruption' of the water, as that term is used in G.L. c. 40, s 39G, and would therefore be unlawful." Kane v. Town of Hudson, 7 Mass. App. Ct. 556, 561 (1979). Similarly here, the corruption or pollution of the waters as a result of cows bathing and drinking in the reservoir likely would be unlawful under the statute, and so could be subject to enforcement by the City through a tort action.

In my opinion, this would be the most effective enforcement option. After serving a demand letter, if compliance is not achieved, we would file a Complaint in Superior Court and seek an injunction from the Court that prohibits the farmer from allowing his cows to trespass and contaminate the public water supply.

Public Health Laws: A local Board of Health may bring an enforcement action pursuant to G.L. c. 111, § 167 for the "protection of sources of water supply" where the deposit of "other matter will corrupt or impair the quality of the water or render it injurious to health." One court, however, has determined that the operation of a piggery near public waters, when connected to agricultural uses, does not constitute a violation of Section 167. Town of Abington v. Cutter, 311 Mass. 715, 722 (1942).

Additionally, pursuant to G.L. c. 111, § 162, Board of Water and Sewer Commissioners or the Mayor may petition the Commonwealth's Department of Public Health (DPH) for pollution abatement if "manure, excrement, garbage, sewage or any other matter pollutes or tends to pollute the waters of any stream, pond, spring, underground waters, or watercourse used by such city … as a source of water supply." After such petition, DPH is required to give notice and hold a public hearing to determine whether the public health requires that the party causing such pollution cease and desist doing so. G.L. c. 111, § 162. If and when an order has issued to cease polluting the public water supply, and if the violation continues, the Commonwealth may bring an enforcement action to collect a $25,000 fine for each day that such violation occurs or continues, or by imprisonment for not more than one year.

STATE AND FEDERAL ENFORCEMENT OPTIONS:

Massachusetts Waters Act: Under state law and the Massachusetts Drinking Water Regulations, 310 CMR 22.00, the Department of Environmental Protection (DEP) is the only entity with the authority to bring enforcement actions regarding drinking water or quality violations. G.L. c. 21, § 44; 310 CMR 22.01. To the extent desired, the City could request DEP's assistance but cannot bring its own enforcement action under the regulations.

Federal Safe Drinking Water Act or Clean Water Act: Similarly, the federal Environmental Protection Agency (EPA) and the Attorney General are entities authorized to enforce federal drinking water acts. While animal waste can constitute a source of pollution under the federal Clean Water Act and Safe Drinking Water Act, it does not appear that the City can bring its own enforcement action under those federal statutes. See 42 USC § 300g-3; United States v. City of North Adams, Mass., 777 F. Supp. 61, 69 (D. Mass. 1991) ("while the State has primary enforcement responsibility, the federal government, if it finds that a public water system does not comply with federal drinking water regulations, will so notify the State" and may bring federal enforcement action). However, the CWA also contains a Citizen Suit provision that would permit the City to enforce the CWA in this instance. 42 USC s. 300j-8 provides "any person may commence a civil action" against another person "who is alleged to be in violation of any requirement prescribed by or under this subchapter." And, under subchapter XII of Title 42, a "person" is defined as an "individual, corporation, company, association, partnership, State, municipality…" 42 USC s. 300f. A Citizen Suit is contingent on providing 60-day notice to the EPA, the alleged violator, and the state. 42 USC s.300j-8(b)(1). In at least one instance, a local entity was allowed to enforce a provision of the CWA under a separate but very similar citizen suit provision of the CWA. Dedham Water Co. v. Cumberland Farms Dairy, Inc., 588 F. Supp. 515, 516-517 (D. Mass. 1983) (citizen suits under 33 U.S.C. s. 1365(b) and 42 U.S.C.A. s. 6972(b)).

POTENTIAL DEFENSES/COUNTERCLAIMS:

Riparian Water Rights/Takings Counter-Claim: Under principles of "riparian water rights," one user of water cannot divert the resource by depriving another valid user of the water of his or her rights to its use. In this regard, we would need to know whether the farmer has acquired any riparian water rights to the reservoir, based either on owning abutting land or past use of the reservoir. If so, we should be wary of a potential "takings" counter claim against any City enforcement action.

For example, in one case, the Town of Hudson had enlarged its public water supply by acquiring a pond that was used by a nearby farmer's cows to drink from, and the farmer sued the Town for compensation because the cows could no longer use the pond. See Fosgate v. Town of Hudson, 178 Mass. 225, 230 (1901). The Town argued that the use of the pond "as a watering place for cattle should, in view of the fact that its waters were used for drinking and domestic purposes, amount to a pollution or contamination of the purity of the water," and thus, was prohibited. Id. The court, however, held that it was appropriate to assess damages for the farmer as against the Town, as the farmer could no longer use the waters for his cattle. Id. See also Kane v. Town of Hudson, 7 Mass. App. Ct. 556, 562 n.3 (1979) ("the probability that the cattle would in fact pollute or contaminate the purity of that water would deprive him of any right to continue such a use" which should be assessed in evaluating damages for takings claim). Similarly here, we should be cautious of a potential takings claim by the farmer.

729641/NBPT/0001

APPENDIX I

American Water Works Association

Dedicated to the World's Most Important Resource®

Government Affairs Office
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Washington, DC 20005-3314
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Working with the NRCS for Source Water Protection

Why work with the Natural Resources Conservation Service (NRCS)?

On December 20, 2018, the President signed the Agriculture Improvement Act of 2018, commonly known as the Farm Bill. That date marked the culmination of an extensive, long-term, and successful effort by AWWA to make source water protection a priority within U.S. Department of Agriculture conservation programs – and to designate significant funding towards those efforts.

Under the new Farm Bill, ten percent of spending on Conservation Title programs is to be directed to source water protection, *providing at least $4 billion over the next 10 years*. These programs assist farmers, ranchers, and forest landowners protect and enhance environmental outcomes that have benefits both on and off-farm. Moreover, there is a now a directive for USDA to work closely with utilities to identify and prioritize areas that need source water protection.

In addition to the funding and prioritization successes, AWWA was also successful in gaining utilities a seat at the table in the state and local groups that decide how, where, on what, and how much of the conservation funds go toward SWP. The NRCS administers most of USDA's conservation programs and working with the Agency is vital if utilities wish to address nonpoint sources such as nutrients, sediment, and chemicals.

In order to assure the successful deployment of these funds to protect source waters, utilities need to come to the table locally with NRCS state technical committees and local work groups to help discuss and prioritize source water protection needs. In-depth information can be found in *USDA Tools to Support Source Water Protection* on AWWA's Source Water Protection resource page and the Source Water Collaborative's Protecting Drinking Water Sources through Agricultural Conservation Toolkit.

Background on NRCS

The NRCS was created in the 1930s to bring the Dust Bowl under control and restore the Nation's agricultural productivity. Concurrent with the Agency's creation was the establishment of local Soil and Water Conservation Districts who help provide direction to the NRCS. Today there are some 11,000 NRCS employees in 3,000 small offices around the country; most of which are co-located with local soil and water conservation districts.

If you need more information, contact your state NRCS office, or Adam Carpenter (acarpenter@awwa.org) or Tracy Mehan (tmehan@awwa.org) at AWWA

NRCS is a technical agency with engineers, agronomists, biologists, soil scientists and a host of other scientific disciplines. NRCS employees provide direct technical and financial assistance to farmers, ranchers and forest land owners. Most work occurs on private lands, which make up 70% of the land area in the lower 48 states.

NRCS is decentralized and organized in each state with a State Office, Area Offices, and multiple Field Offices (generally one in each county). NRCS also has offices on Tribal lands. *NRCS office contacts can be found at https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/contact/states/.*

Opportunities for Engagement
For utilities interested in engaging with the NRCS, there are four key individuals to contact:
1. State Conservationist – responsible for all NRCS activities in the state;
2. Assistant State Conservationist for Programs – responsible for all NRCS programs;
3. Area Conservationist – responsible for operations and programs in a multi-county area;
4. District Conservationist – responsible for the Agency's work, usually within a county.

When contacting the State Office, explain your interest and ask what the Agency is doing for SWP in your area. Also inquire about becoming a member of the State Technical Committee and/or a Local Work Group. NRCS also has Tribal Conservation Advisory Councils. These committees are established under law and provide official ways to influence NRCS decisions. Members of State Technical Committees and Local Work Groups come from a wide variety of natural resource and agricultural interests and include representatives from Federal and State natural resource agencies, Indian Tribes, agricultural groups, environmental organizations, and agricultural producers. The committee meets regularly to provide information, analysis, and recommendations to USDA officials, who strongly consider their advice.

Utilities wanting to participate as members on a State Technical Committee may submit requests to the State Conservationist explaining their interest and relevant credentials. To become a member of the Local Work Group, contact the District Conservationist in your county.

State Technical Committee Role
- Provide information, analysis, and recommendations to USDA on conservation priorities and criteria for natural resources conservation activities and programs, including application and funding criteria, recommended practices, and program payment percentages.
- Identify emerging natural resource concerns and program needs.
- Recommend conservation practice standards and specifications and program policy.
- Review and make recommendations ensure State priorities are being addressed locally.
- Assist with public outreach and information efforts and identify educational and producer needs.

Local Work Group Role
- Help identify program funding needs, resource concerns, and conservation practices at the local level;
- Recommend program application and funding criteria, eligible practices, limits on practice payments, and payment rates;
- Participate in multicounty coordination; and
- Assist with public outreach and information efforts and identify training needs

USDA United States Department of Agriculture

Conservation Stewardship Program for Dairy Producers

Have you ever looked across your land and thought about some operational management goals you would like to take to the next level? Maybe we can help.

No one knows more about your land than you do, and no one knows more about conservation than we do. Together we can develop a plan tailored to your operation and your goals to help you increase productivity and protect the value of your land.

The Conservation Stewardship Program (CSP) offers an opportunity for dairy producers to enhance their agricultural operations while adopting conservation activities that can reduce energy use, improve soil health, and improve water quality. CSP can help you plan and implement conservation practices and enhancements that address natural resource concerns on your operation.

What's new?

Dairy producers continue to benefit from all that CSP has to offer. There are a number of enhancements applicable to dairy production Examples of enhancement options available to dairy producers are nutrient management activities to enhance air quality, buffers to enhance water quality and water management activities.

The new CSP provides adaptive management options to better respond to market and weather conditions, allowing participants to choose enhancements, or bundles of enhancements, that best fit their unique circumstances.

Is CSP for you?

CSP helps you build on your existing conservation efforts while strengthening your operation. Whether you are looking to reduce concentration of nutrients, implement prescribed grazing, or develop wildlife habitat, we can custom design a CSP plan to help you meet those goals. We can help you with drainage water management, apply treated manure to your land, or schedule cover crop planting that utilizes residual nitrogen. If you are already taking steps to improve the condition of the land, chances are CSP can help you find new ways to meet your goals. CSP contracts are for five years, with the option to renew.

Types of Assistance

NRCS provides free technical assistance to all agricultural producers. To participate in CSP and receive financial assistance, producers must control or own the land and be in compliance with highly erodible land and wetland conservation requirements, and have current farm records with USDA Farm Service Agency. Learn more at **www.nrcs.usda.gov/farmbill**.

Where can I get more info?

To learn more about CSP opportunities, dairy producers should contact their local USDA service center and set up an appointment with NRCS staff. A Local Service Center Directory is available online at **www.nrcs.usda.gov,** then click "Contact Us." You can also visit our CSP page online at **www.nrcs.usda.gov/CSP.**

Natural Resources Conservation Service

nrcs.usda.gov

CSP Enhancements to assist Dairy Producers

(This is not an exhaustive list.)

Livestock and Wildlife

- Manage Livestock Access to Water Sources
- Wildlife Corridors
- Grazing Management to Improve Wildlife
- Forage Harvest Management
- Bird Habitat
- Pollinator and/or Beneficial Insect Habitat

Nutrient & Pest Management

- Precision Pesticide Application
- Enhancements to Reduce the Concentration of Nutrients
- Drainage Water Management
- Herbaceous Weed Control
- Land Application of Treated Manure
- Use Non-chemical Methods to Terminate Cover Crops

Pastureland

- Native Grasses or Legumes Planting
- Prescribed Grazing
- Enhancements to Improve Plant Productivity and Health
- Maintain Quantity and Quality of Forage
- Improve Nutrient Uptake and Efficiency
- Cover Crop Enhancements to Utilize Residual Nitrogen
- Enhancements to Use Natural Sources of Nitrogen (legumes, manure, compost)

Natural Resources, Biodiversity & Buffers

- Add Food-Producing Trees and Shrubs to Existing Plantings
- Field Borders
- Riparian Buffers
- Filter Strips
- Critical Area Plantings

FAQ frequently asked questions

How can I find out if I am eligible?

The best way to determine eligibility is to contact your local field office. You must meet Adjusted Gross Income (AGI) requirements and have a Farm Tract Number with FSA. Land already enrolled in some USDA Farm Bill programs, such as CRP and some easement programs, may not be eligible.

Is there a minimum number of acres needed to be enrolled?

No, but entire operation must be enrolled.

Is there a minimum contract payment?

Yes, $1,500 annually.

What are "resource concerns?"

NRCS conservation specialists conduct resource inventories on agricultural land to evaluate natural resources including soil, water, air, plant, and animal resource bases to determine their condition. If there is a cause or threat to that resource, that can result in what we refer to as a resource concern. Examples of resource concerns are erosion, degraded water quality, and plant health.

What are "enhancements?"

Enhancements are management activities that go above and beyond the minimum practice requirements helping the producer achieve a higher level of conservation.

What are "bundles?"

Bundles are suites of conservation enhancements designed to address multiple resource concerns. Bundle options are offered at a higher payment rate.

Do I have options to pick the enhancements that are best suited for my operation?

Yes. The variety of CSP practices that are offered give you a lot of freedom to select enhancements that help you meet your management goals.

COLLABORATION TOOLKIT

PROTECTING DRINKING WATER SOURCES THROUGH AGRICULTURAL CONSERVATION PRACTICES

Are you interested in getting more agricultural conservation practices on the ground to help protect sources of drinking water? If you're working at the state level, a natural ally is the Natural Resources Conservation Service (NRCS) State Conservationist's office (part of the U.S. Department of Agriculture).

This toolkit, developed as a result of extensive collaboration between members of the Source Water Collaborative and the NRCS, offers a step-by-step approach. The resources inside are useful for anyone working in source water protection: from those who already know their State Conservationist, but may be looking for new ideas, to those aiming to build a successful relationship. Each insightful tip is based on advice we received from NRCS and from state and regional source water coordinators who recently fostered effective partnerships.

EASY-TO-FOLLOW STEPS

The toolkit includes simple steps for identifying common ground, opportunities, and key contacts and ideas for working with USDA at the state level.

- Step 1 gives a quick overview of key USDA conservation programs that help protect and improve sources of drinking water. Learn the vocabulary NRCS staff use so you're sure to speak their language.
- Step 2 gives tips to help you define what your source water program can offer and includes an infographic that explains the State Conservationist's role and what can be accomplished through collaboration.
- Step 3 links to talking points, draft agenda for first meeting, and key USDA documents to help you take the first steps to action.
- Step 4 lists useful conservation and source water protection resources as well as current opportunities in your state and success stories.
- Step 5 links to key partners who can bring data, technical capabilities, useful state and local perspectives, and links to other key stakeholders.
- Step 6 gives information on how to easily stay connected.

*Visit www.sourcewatercollaborative.org/swp-usda to access the Collaboration Toolkit, which includes links to these websites and resources.

Want to collaborate with local conservation districts to get agricultural conservation practices in place to protect drinking water sources?

The Source Water Collaborative is also working to develop a local supplement to this toolkit through our partnership with the National Association of Conservation Districts. By early 2013 this toolkit will include a step-by-step process for collaborating with conservation districts.

STEP 1 UNDERSTAND HOW KEY USDA CONSERVATION PROGRAMS CAN HELP PROTECT AND IMPROVE SOURCES OF DRINKING WATER

Source water protection results when key state and local leaders and stakeholders collaborate to encourage land use practices that protect and improve water quality – for agriculture this means systems of conservation practices. USDA has a suite of voluntary programs implemented at the state and local level that provide financial assistance to willing private landowners and operators* to protect and improve soil and water quality.

This online guide is intended to provide background information and some simple steps to help connect source water stakeholders and USDA leadership at the state and local levels, to encourage a collaborative approach to protecting and improving water quality and our sources of drinking water.

USDA

Natural Resources Conservation Service (NRCS)

**under the Under Secretary for Natural Resource and Environment*

NRCS provides technical and financial assistance to private landowners and operators for their voluntary implementation of systems of conservation practices.

Some of their key partners include the National Association of Conservation Districts and the National Association of State Conservation Agencies.

- NRCS and source water protection programs share a common goal of protecting and improving water quality, and both are voluntary programs

  – State Conservationists have decision-making authority and considerable flexibility to offer technical and financial assistance to private landowners and operators.

  – Specific projects can bring key partners to the table to leverage resources and expertise to protect and improve watersheds that yield drinking water.

Farm Service Agency

**under the Under Secretary for Farm and Foreign Agricultural Services*

FSA provides farm commodity, credit, conservation, disaster, loan, and price support programs.

- FSA has two important programs directly protecting sources of drinking water:

  – Source Water Protection Programs, with National Rural Water Association: This Map shows the 33 states where rural source water technicians provide technical assistance to identify priority areas, and work with local teams to develop Rural Source Water Protection plans to protect ground water sources of drinking water through adoption of voluntary practices, including conservation practices

  – The Conservation Reserve Enhancement Program (CREP) is a voluntary land retirement program that helps agricultural producers protect environmentally sensitive land, decrease erosion, restore wildlife habitat, and safeguard ground and surface water. CREP is an offshoot of the country's largest private-lands environmental improvement program - the Conservation Reserve Program (CRP).

This is just a quick introduction. More details about NRCS and FSA organization and staff are provided in the following steps.

Note: This information presents just a limited view of USDA offices and programs that are relevant to source water protection efforts. A complete USDA organization chart can be found at: **http://usda.gov/wps/portal/usda/usdahome?navid=USDA_ORG_CHART**

STEP 2 DEFINE WHAT YOUR SOURCE WATER PROGRAM CAN OFFER

Consider reaching out to NRCS or FSA staff in your locality or state to help your source water protection efforts. In Step 1, you read a brief overview to help orient you to NRCS and FSA. Now, you'll need to consider what you (or your source water program) can offer. Here are a few ideas to help you get started:

- Understand NRCS/FSA programs and specific state information through a quick check of these websites: nrcs.usda.gov (browse by location – NRCS State Offices) and fsa.usda.gov (State Offices tab).
- Note that NRCS and FSA staff (and the private landowners and operators they work with) may be most aware of the regulatory nature of state and federal environmental programs, so it is important to convey that your focus is on opportunities to work collaboratively and voluntarily.
- Identify a specific geographic area or project to propose for collaboration, where systems of conservation practices could help protect and improve drinking water sources.
- Share source water data, particularly GIS maps and source water assessment results, with NRCS and FSA to identify opportunities to protect and improve water quality, and sources of drinking water. Link source water data to geographic areas where NRCS/FSA programs could protect water quality. Be aware that USDA does not share locational, ownership, or other specific information about farms, ranches or other properties – this is covered by Farm Bill Section 1619 (confidentiality of producer information). However, NRCS and FSA can share aggregated information on systems of conservation practices or acres with conservation practices.
- Consider how source water protection partners could help promote private landowner and operator participation or document progress by monitoring water quality.

The following infographic highlights what source water programs and NRCS State Conservationists can bring to a collaborative effort to protect sources of drinking water.

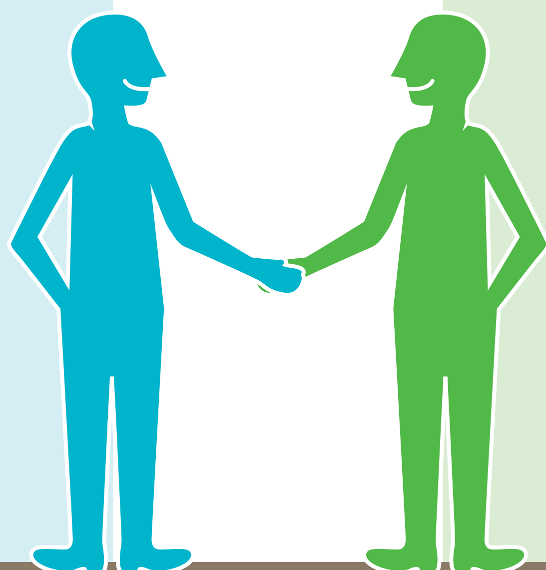
COLLABORATION CAN PROTECT SOURCES OF DRINKING WATER

TOGETHER

- Align our work for mutual program benefits
- Leverage funding
- Include multiple partners
- Measure progress
- Help private landowners and operators, agencies, and partners know they are helping a bigger picture

STATE SOURCE WATER PROGRAM

- Share data and information on delineated source water protection areas, priority contaminants, sources of contamination, and water quality monitoring results
- Provide information and leverage potential funding sources
- Assist with implementation and help target USDA initiatives (e.g., identifying priority areas, potential benefits of conservation practices to drinking water)
- Partner in conducting outreach to private landowners and operators



STATE CONSERVATIONIST

- Implement NRCS conservation programs – technical assistance and funding to private landowners and operators for conservation plans, and cost-share for conservation practices
  - EQIP (water quality initiatives)
  - State 590 conservation practice standards
  - Conservation Stewardship Program
- Funding capacity, and discretion about what to fund
- Agreements with partners (e.g., conservation districts)
- Discretionary technical assistance (e.g. signup workshops for private landowners and operators to help implement a water quality improvement project)

OUR COMMON GROUND

- Voluntary (non-regulatory) programs for private landowners and operators
- Focus on protecting soil, water quality, and health
- Help assure overall health of communities
- Achieve and demonstrate water quality results in priority areas

Note: It's a good idea to find out who USDA NRCS work with in your state. We are using "private landowners and operators" as a general term in this infographic. NRCS may work with a variety of producers - farmers, ranchers, poultry and livestock producers, dairymen, forest landowners, including those who rent land.

SOURCE WATER PROTECTION & USDA CONSERVATION PROGRAMS: WHAT ARE THE OPPORTUNITIES?

WHAT IS SOURCE WATER?

Source water includes all current and future sources of drinking water:

- Surface water (rivers, streams, lakes and reservoirs)
- Ground water (aquifers)

WHAT IS SOURCE WATER PROTECTION?

Actions to prevent drinking water contamination to protect public health and local economy, and lower drinking water treatment costs.

HOW DOES SOURCE WATER PROTECTION WORK?

Problem identification: Assessments of potential threats, sources and vulnerability

Source Water Protection Plans: Community or subwatershed scale (HUC-12 or smaller), to address priority contaminants and their sources

State and Local Partnerships: Local, state, and federal policies, programs, and voluntary actions that together can keep contaminants from entering sources of drinking water

- **Local partners:** public water systems, community leaders and land-use decision makers, agricultural leaders, and the public
- **State partners:** state land use and water agencies
  - State drinking water programs implement source water programs; may be in environmental or public health departments
  - State clean water programs implement Clean Water authorities, e.g. 319 grants, TMDLs; generally in environmental or natural resources departments
- States can fund many source water protection activities through the Drinking Water and Clean Water State Revolving Funds (SRFs) and can work with other state and other federal funding programs to protect sources of drinking water when those programs develop priority ranking factors for projects that include drinking water source water protection

SOURCE WATER & CONSERVATION PARTNERSHIP OPPORTUNITIES

- Developing updated state 590 standards
- Implementing National Water Quality Initiative in priority watersheds
- Implementing NRCS conservation programs and Landscape Conservation Initiatives
- State nutrient strategies
- Specific source water protection projects

HOW TO CONTACT YOUR FEDERAL AND STATE SOURCE WATER PROTECTION PROGRAMS

State Source Water Program Contacts:
www.asdwa.org/sourcewatercontacts

EPA Regional Source Water Protection Coordinators:
http://water.epa.gov/infrastructure/drinkingwater/sourcewater/protection/epaheadquartersregionalandstatecontacts.cfm

TAKE ACTION

STEP 3

Visit www.sourcewatercollaborative.org/swp-usda to access the Collaboration Toolkit, which includes links to these websites and resources.

NRCS and FSA are two USDA agencies that can provide technical and financial assistance for systems of conservation practices on working and retired lands. These programs benefit water quality. NRCS state offices will have the broadest perspective regarding available conservation programs and priorities. Key NRCS state contacts, information about Local Working Groups, and tips to help you reach out are identified below.

Natural Resources Conservation Service (NRCS)

CALL YOUR ASSISTANT STATE CONSERVATIONIST FOR WATER PROGRAMS TO SCHEDULE A MEETING

Based on feedback from NRCS, we suggest you start by contacting your Assistant State Conservationist for Programs. Some State Conservationist's offices may suggest a different point of contact. In your initial conversation, so that you identify the right contacts, be clear that you are seeking to develop a partnership based on mutual understanding of source water concerns and NRCS programs that can protect sources of drinking water in your state. Once you have the initial conversation, they may refer you to the Resource Conservationist, or others.
Visit www.sourcewatercollaborative.org/swp-usda to find:

- A handy organizational structure
- Your State Conservationist's office contact information
- Tips to help you set up a meeting. A good first step is to meet with the Assistant State Conservationist for Programs
- Draft talking points for your meeting

PRINT THE PREVIOUS PAGES AS A "LEAVE-BEHIND" FOR YOUR MEETING. IT SUMMARIZES KEY ELEMENTS OF SOURCE WATER PROTECTION

PARTICIPATE IN A STATE TECHNICAL COMMITTEE (STC) MEETING AND CONSIDER JOINING AS A MEMBER

STCs provide advice and recommendations to State Conservationists and guidance to Local Working Groups. After you get to know your STC, you may want to give a presentation to the group.
Visit www.sourcewatercollaborative.org/swp-usda for these resources that will help you get started.

- A quick overview of STCs
- Information about NRCS Local Working Groups
- A quick overview of Local Working Groups
- NRCS's eDirective on Local Working Groups
- Basic source water protection slides you might borrow from to insert into a more specific state presentation to your State Technical Committee

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STEP 4

FIND RESOURCES

Visit www.sourcewatercollaborative.org/swp-usda to access the Collaboration Toolkit, which includes links to these websites and resources.

USEFUL CONSERVATION RESOURCES

- Overview of NRCS & FSA Conservation Programs
- Find Local or State Contacts through the National Association of Conservation Districts
  - State Contacts
  - Local Districts
- NRCS Conservation Practices

USEFUL SOURCE WATER RESOURCES

- State Drinking Water Programs
- Find Allies through the Source Water Collaborative
- Maps of nutrient loading and drinking water: Nitrogen & Phosphorus Pollution Data Access Tool
- From Field to Faucet: Protecting Your Drinking Water
- Watershed Projects (Watershed Central)

Current Opportunities

Use the steps in this toolkit to contact your NRCS State Conservationist's office about these current opportunities in your state.

- NRCS Nutrient Management Conservation Practice Standard 590 – Updated State Standards due to NRCS January 2013
- The 2013 USDA National Water Quality Initiative (NWQI) offers an opportunity to increase installation of conservation practices to address nutrient concerns for drinking water sources in selected watersheds. States can work with NRCS to identify additional watersheds in FY 2013.

  – Coordinate with your state's Clean Water Act Section 319 program, and contact your State Conservationist's office to provide input to watershed selection.

Visit www.sourcewatercollaborative.org/swp-usda to access these resources and read more

Learn About Others' Success

Success Stories

These case studies demonstrate key steps in partnering source water protection USDA programs:

- **Indiana (Wellhead protection)**
- **Iowa (Little River Lake)**
- **New Hampshire/Maine (Salmon Falls Watershed)**
- **Minnesota**
- **North Carolina**
- **Pennsylvania (Maiden Creek Watershed)**

Visit www.sourcewatercollaborative.org/swp-usda to access these case studies

COORDINATE WITH OTHER PARTNERS

Visit www.sourcewatercollaborative.org/swp-usda to access the Collaboration Toolkit, which includes links to these websites and resources.

Partnerships can enhance the likelihood that your project will be successful. Partners bring data, technical capabilities, useful state and local perspectives, link to other key stakeholders, and sometimes have resources to support project elements. Including key partners in your project-specific meeting with the State Conservationist or the Assistant State Conservationist for Programs can strengthen your presentation and make the discussion more productive.

- EPA Regional Source Water Protection Contacts
- State Source Water Program contacts
- State Clean Water Programs
  - – Reach out to your state Clean Water Act 319 program and engage with them in identifying priority watersheds for the National Water Quality Initiative. Provide coordinated input to the State Conservationist and State Technical Committee.
  - – Clean Water Act section 319 funds have supported source water protection projects. Explore the possibility of linking your project to watershed plans developed for section 319 projects.
  - – Find state 319 programs.
  - – Find EPA regional contacts for tribal 319 programs.
- National Estuary Programs
- Drinking Water Utilities & Municipalities
  - – Find Your Water System
- Cooperative Extension System & State Land Grant Universities
  - – Find your state or local extension office
- Other Federal Agencies
  - – US Forest Service
    - Forests to Faucets map: Visit www.sourcewatercollaborative.org/swp-usda for an interactive map that illustrates the crucial role forests play in sustaining the quality of surface drinking water and more information on forests and the drinking water supplies they protect in New England and the upper Midwest.
    - Forest Action Plans
    - i-Tree Tools
  - – US Geological Survey
    - http://water.usgs.gov/nawqa/
    - http://water.usgs.gov/nawqa/nutrients/
    - http://water.usgs.gov/nawqa/studies/public_wells/
    - http://water.usgs.gov/nawqa/studies/domestic_wells/

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STEP 6 COMMUNICATE YOUR SUCCESS & STAY UP-TO-DATE

Share Your Feedback

Let us know how you used the information in this toolkit by sending an email to the SWC. We'd like to hear your successes and continuing challenges. Your feedback will help us continue to improve this toolkit.

Email the SWC: info@sourcewatercollaborative.org.

Promote the Toolkit

Help get the word out to source water colleagues by promoting this toolkit at your next meeting, conference, or through emails and newsletters. Visit www.sourcewatercollaborative.org/swp-usda to download:

- A two-page handout
- PowerPoint slides that explain the toolkit (Useful for your next workshop or meeting.)
- A brief narrative describing the toolkit, along with supportive quotes. (Useful for email, newsletter, web, social media updates to your members and colleagues)

Stay Up-to-Date

Sign up for email alerts and we'll let you know when the toolkit is updated with new resources.
Visit www.sourcewatercollaborative.org/swp-usda to sign up.

STEP 2 DEFINE WHAT YOUR SOURCE WATER PROGRAM CAN OFFER

Consider reaching out to NRCS or FSA staff in your locality or state to help your source water protection efforts. In Step 1, you read a brief overview to help orient you to NRCS and FSA. Now, you'll need to consider what you (or your source water program) can offer. Here are a few ideas to help you get started:

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- Note that NRCS and FSA staff (and the private landowners and operators they work with) may be most aware of the regulatory nature of state and federal environmental programs, so it is important to convey that your focus is on opportunities to work collaboratively and voluntarily.
- Identify a specific geographic area or project to propose for collaboration, where systems of conservation practices could help protect and improve drinking water sources.
- Share source water data, particularly GIS maps and source water assessment results, with NRCS and FSA to identify opportunities to protect and improve water quality, and sources of drinking water. Link source water data to geographic areas where NRCS/FSA programs could protect water quality. Be aware that USDA does not share locational, ownership, or other specific information about farms, ranches or other properties – this is covered by Farm Bill Section 1619 (confidentiality of producer information). However, NRCS and FSA can share aggregated information on systems of conservation practices or acres with conservation practices.
- Consider how source water protection partners could help promote private landowner and operator participation or document progress by monitoring water quality.

The following infographic highlights what source water programs and NRCS State Conservationists can bring to a collaborative effort to protect sources of drinking water.

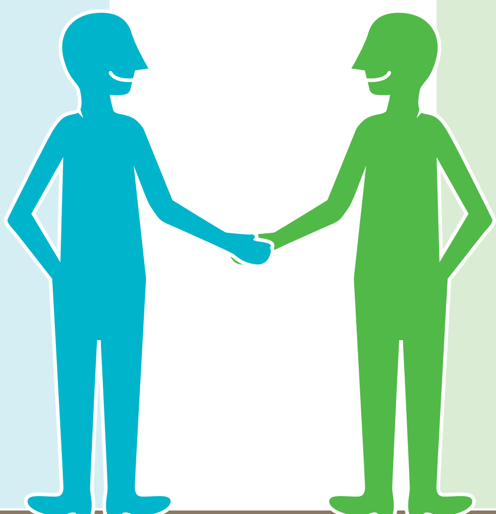
COLLABORATION CAN PROTECT SOURCES OF DRINKING WATER

TOGETHER

- Help NRCS direct 10 percent of conservation program spending to source water protection (2018 Farm Bill)
- Leverage funding
- Include multiple partners
- Measure progress
- Help producers and private landowners, agencies, and partners create a more sustainable future

STATE SOURCE WATER PROGRAM

- Share data and information on delineated source water protection areas, priority contaminants, sources of contamination, and water quality monitoring results
- Provide information and leverage potential funding sources
- Assist with implementation and help target USDA initiatives (e.g., identifying priority areas, potential benefits of conservation practices to drinking water)
- Partner in conducting outreach to private landowners and operators
- Help engage drinking water utilities and other source water protection stakeholders
- Contact: asdwa.org/sourcewatercontacts



STATE CONSERVATIONIST

- Implement NRCS conservation programs – technical assistance and funding to private landowners and operators for conservation plans, and financial assistance for conservation practices
  - Environmental Quality Incentives Program (EQIP)
  - National Water Quality Initiative (NWQI) Source Water Pilot
  - Regional Conservation Partnership Program (RCPP)
  - Joint Chiefs Landscape Restoration Partnership
  - Conservation practice standards
- Funding capacity, and discretion about what to fund
- Agreements with partners (e.g., conservation districts)
- Discretionary technical assistance (e.g. signup workshops for private landowners and operators)
- Contact: nrcs.usda.gov/wps/portal/nrcs/main/national/contact/states/

OUR COMMON GROUND

- Voluntary (non-regulatory) programs for private landowners and operators
- Focus on protecting soil,water quality, and health
- Help assure overall health of communities
- Achieve and demonstrate water quality results in priority areas

Note: It's a good idea to find out who USDA NRCS work with in your state. We are using "private landowners and operators" as a general term in this infographic. NRCS may work with a variety of producers - farmers, ranchers, poultry and livestock producers, dairymen, forest landowners, including those who rent land.

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SourceWaterCollaborative.org

The Source Water Collaborative, twenty-nine national entities representing federal, state, and local partners, works together to protect drinking water sources for generations to come.

2018 FARM BILL EMPHASIZES PROTECTION OF DRINKING WATER SOURCES

H.R. 2 – 92

(d) SOURCE WATER PROTECTION THROUGH TARGETING OF AGRICULTURAL PRACTICES - Section 1244 of the Food Security Act of 1985 (16 U.S.C. 3844) (as amended by subsection (b)) is amended by adding at the end the following:

"(n) SOURCE WATER PROTECTION THROUGH TARGETING OF AGRICULTURAL PRACTICES.

"(1) IN GENERAL.—In carrying out any conservation program administered by the Secretary, the Secretary shall encourage practices that relate to water quality and water quantity that protect source water for drinking water (including protecting against public health threats) while also benefitting agricultural producers.

"(2) COLLABORATION WITH WATER SYSTEMS AND INCREASED INCENTIVES.

"(A) IN GENERAL.—In encouraging practices under paragraph (1), the Secretary shall

"(i) work collaboratively with community water systems and State technical committees established under section 1261(a) to identify, in each State, local priority areas for the protection of source waters for drinking water; and

"(ii) subject to subparagraph (B), for practices described in paragraph (1), offer to producers increased incentives and higher payment rates than are otherwise statutorily authorized by the applicable conservation program administered by the Secretary.

"(B) LIMITATION.—An increased payment under subparagraph (A)(ii) shall not exceed 90 percent of practice costs associated with planning, design, materials, equipment, installation, labor, management, maintenance, or training.

"(3) RESERVATION OF FUNDS.

"(A) IN GENERAL.—In each of fiscal years 2019 through 2023, the Secretary shall use to carry out this subsection not less than 10 percent of any funds available for conservation programs administered by the Secretary under this title (other than the conservation reserve program established under subchapter B of chapter 1 of subtitle D).

"(B) LIMITATION.—Funds available for a specific conservation program shall not be transfered to fund a different conservation program under this title.".

Tips for Requesting a Meeting with Your Assistant State Conservationist for Programs

Important Background Note: This online tool and linked materials were shared with State Conservationists (and includes input from NRCS).

Before You Make the Call

- ✓ **Review the NRCS background information** and take a quick tour of your state NRCS website.
- ✓ **Keep in mind that the State Conservationist may be new to the position** (NRCS offers many opportunities to move around), so the Assistant State Conservationist may be interested in providing updated information on specific projects & partnership opportunities to the State Conservationist.
- ✓ **Think about your goals -** you are taking the first step in building a relationship with a potential partner, with whom you share a mutual interest in water quality. You may find that you have some common goals; you may also find that you use different terms for water quality, and need to do some "translating." For example, people may not understand that source water protection can include protecting pristine waters and addressing contamination, through approaches that prevent or reduce contaminants entering water.
- ✓ **Keep in mind that NRCS has a network of partners at the state and local level,** so they are accustomed to partnerships, but they may not be familiar with source water protection. You can provide valuable insight into your state's source water protection program.
- ✓ **Identify GIS maps and other source water data** that will illustrate source water protection priority geographic areas and contaminants. A picture really is worth a thousand words – do you have any before and after pictures where water quality has been restored for drinking water, or that illustrate a priority source water problem?
- ✓ If possible, **identify a specific source water protection project** where conservation practices could reduce threats from agricultural pollutants.
- ✓ **Consider including your state 319 program coordinator in the meeting**. He/she may already have a working relationship with NRCS, or may appreciate the opportunity to build this relationship. NRCS may appreciate understanding how state water programs work. And there are three key opportunities for collaborating with your state 319 program to provide input to NRCS:
  - 2013 National Water Quality Initiative: identifying priority watersheds or assisting in with existing watersheds *(Note: It is important to recognize that not all states will be selecting new watersheds, some of them will continue work on the ones selected in FY12.)*
  - State 590 Nutrient Management Standard: states must update their standards by January 2013
  - State Nutrient Strategies: many states are developing state nutrient strategies, including identifying high priority watersheds for nutrient reduction

Making the Call

- ✓ Call your State NRCS (use the Find Your State Conservationist document linked in Step 3 of the SWC online toolkit), identifying yourself and your association with protecting sources of drinking water. Ask to speak with the Assistant State Conservationist for Programs.
- ✓ During the call, briefly explain your reason for reaching out to NRCS. If you are able to speak with the Assistant State Conservationist for Programs, mention your mutual interest in protecting water quality, and in a voluntary approach to engaging farmers or landowners.
- ✓ Request a 30-60 minute meeting with the Assistant State Conservationist for Programs, and any others he/she recommends (e.g. some states have an Assistant State Conservationist for Water Resources, or the State Conservationist may be available to meet).

At the Meeting

- ✓ Clearly state your purpose for meeting
- ✓ Share your source water protection story
- ✓ Identify next steps and who else to engage

USDA Tools to Support Source Water Protection

June 2018

American Water Works Association

The Challenges of Excess Nutrients

Nutrient pollution is increasingly seen as a major problem for safe drinking water. In 2014, 400,000 residents of Toledo, Ohio lost their public drinking water for three days due to cyanotoxins in the city's drinking water source. In 2015, a 650-mile cyanobacterial bloom on the Ohio River threatened multiple water treatment plants. Numerous other areas have seen either persistent or growing concerns surrounding cyanotoxins.

Although cyanobacterial blooms are not exclusively the result of nutrients, excess nutrient loading is one major factor in creating the right conditions. Both utilities and the farming community have incentives to reduce runoff – utilities to protect water resources and farmers to improve agricultural yield by keeping nutrients on their land. States continue to develop guidelines and regulations on the management of cyanotoxins in water supplies. Yet in many instances, the underlying issues triggering increased cyanobacterial blooms can be addressed or at least reduced at the source.

Nitrogen contamination is a related concern. High levels of nitrates in drinking water can be dangerous for infants. In 2015, 183 community water systems exceeded allowable levels of nitrate in drinking water. Although this represents a small percentage of the nation's 51,000 community water systems, reducing nitrates is an opportunity to address a real risk. Whether in areas with dense agriculture like Iowa, Great Lakes states like Ohio, or elsewhere across the country, treatment facilities are facing enormous costs handling excess nutrient levels in drinking water.

Agricultural producers are only one piece of the puzzle in addressing excessive nutrients, sediment, and chemicals; cities and others have a major role to play as well. AWWA believes proactive partnerships between water utilities and agricultural producers are an important tool in dealing with these resource concerns.

Source Water Protection

Recognizing the old saying that "an ounce of prevention is worth a pound of cure," many utilities have invested in various forms of source water protection to safeguard their supplies. In some cases, the benefits clearly outweigh the costs. For example, a utility might avoid or delay installing new treatment, reducing treatment chemical costs. Other times, the cost-benefit calculation can be more challenging. Keeping in mind that some benefits are not easily quantified (e.g., the value of risk reduction, increased public confidence, and long-term improvements to watershed health), investing in source water protection can be more easily justified when those who share in the benefits also share some of the expense. This multi-beneficiary and multi-payer approach is a key opportunity in working with agricultural conservation programs, as many organizations can achieve their goals simultaneously by contributing to a project that has many benefits.

The Natural Resources Conservation Service (NRCS) provides many opportunities for collaboration, and utilities also can work with organizations such as the U.S. Endowment for Forestry and Communities in areas involving forested lands. Local agricultural associations, soil and water conservation districts, and other local and regional organizations can often bring useful partnerships, expertise and resources to projects.

Source water protection programs take many forms, such as spill prevention and response planning, stakeholder education, coordination with upstream point source dischargers, and addressing upstream nonpoint sources. Although all methods of source water protection are important, this document focuses specifically on collaborations between water systems and the agricultural community, which includes farmers, ranchers, forest landowners and their partners. We encourage utilities seeking information on source water protection practices to review AWWA's Source Water Protection Resource Community as well as AWWA's G300 standard on source water protection and to consult with relevant state and local partners.

Utilities can begin to address the challenge of excess nutrients (and/or other local challenges as appropriate) by taking advantage of cost sharing offered by NRCS and other resources available by local partners. However, for project applications to be successful, utilities must first establish relationships and build trust with potential agricultural sector partners.

Why should a utility get involved with the agricultural community?

There are many reasons why utilities should be involved in agricultural conservation projects in their watersheds. Through involvement with the agricultural sector, utilities can take the following actions:

1. Help to shape how conservation dollars are spent, focusing them on the greatest benefits to source water protection.
2. Foster mutual trust and understanding between water systems and farmers, encouraging constructive problem-solving.
3. Make progress on specific source water concerns by focusing on practices that will best address them.
4. Save on treatment costs or delay or avoid installing additional treatment.
5. Reduce risks to their water supplies.
6. Increase public confidence in both sectors.
7. Leverage every dollar they contribute (whether cash or in-kind) through NRCS and other partners. For example, in the Beaver Water District case study described on page 6, about $8.50 is being spent on implementing best management practices (BMPs) for every $1 contributed by the utility.

Getting Started–Water Utilities

1. Review programs and case studies (this document)

Identify programs or projects that align with your utility's needs

2. Contact your local NRCS office

Tell them you are interested in X, have Y concerns, and would like to explore possible collaborative solutions…

3. Contact your local Conservation District

Ask about their programs and opportunities to partner, etc.

Opportunities for Direct Engagement

Water utilities have multiple opportunities to engage with the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) and local Conservation Districts. USDA has a suite of programs that helps farmers, ranchers, and landowners protect wildlife habitat, water, soil and air quality. USDA spends nearly $6 billion a year to help farmers and ranchers implement conservation practices and provide them with technical assistance, with almost two-thirds of it administered locally and regionally through the NRCS. Many of these NRCS conservation programs share goals with source water protection programs, even if the conservation programs have not specifically targeted protecting drinking water. Utility engagement with these entities helps to identify activities that benefit source water protection and assist the agricultural community.

Natural Resources Conservation Service (NRCS)

Nationally, NRCS has 3,100 field offices, covering all 50 states and most U.S. territories and allied states. Generally, the offices are more common in areas with more agricultural activity. However, *there is at least one NRCS office offering services covering the source water area for nearly every utility across the country.* That means that there are dedicated professionals working with the agricultural community in and around your watershed. By getting to know these professionals, your water resource concerns can be heard and you can seek out opportunities for collaboration. To find the closest

Interested in conservation in Canada?

Most of the information about programs and offerings contained in this document is specific to the United States. However, Canadian provinces also host programs that involve utility collaboration utilities can get involved in, although they will likely differ considerably from the U.S. based programs. For example, Alberta has regional land use planning frameworks, as well as Watershed Planning and Advisory Councils. Canadian utilities can reach out to the relevant ministries and agricultural groups in their provinces to see how they can get involved in advancing source water protection in collaboration with agriculture.

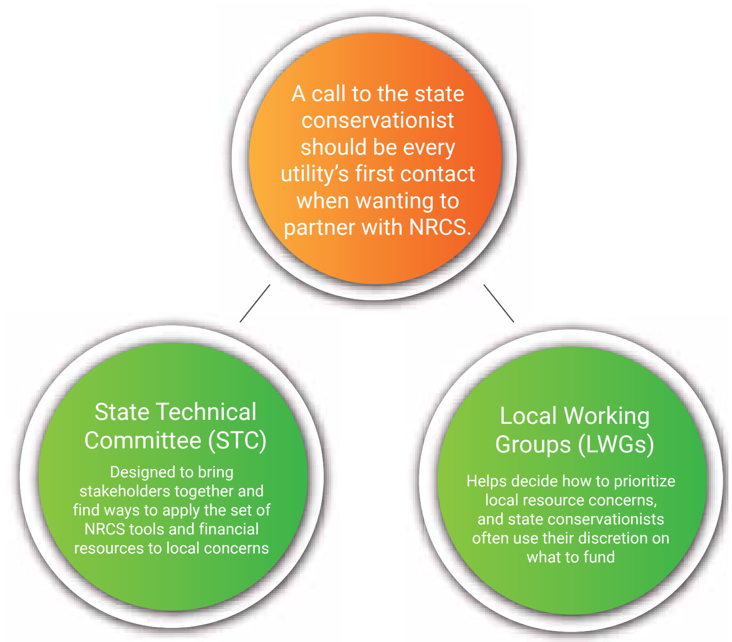
Other USDA Programs

In addition to the many conservation programs run by NRCS and other USDA offices, other resources available from USDA provide support through research opportunities, information resources, and other partnership options. Utilities should consider reaching out to these resources where appropriate to the proposed project.

- The Agricultural Research Service
- The Climate Hubs
- The Economic Research Service
- The Farm Service Agency
- The National Agricultural Statistics Service
- The National Institute for Food and Agriculture (including the Extension Network)
- The Rural Utilities Service

local office, consult the USDA Service Center Locator.

Contact your State Conservationist or Assistant State Conservationist for Local Programs



To find your state conservationist, consult the NRCS State Conservation Office Directory.

Additional information on engagement with State Technical Committees

State Technical Committees serve in an advisory capacity to NRCS. They provide information, analysis, and recommendations to NRCS on conservation priorities and criteria for conservation activities and programs, including application and funding criteria, recommended practices, and program payment percentages. They also identify emerging natural resource concerns and program needs, and review recommendations of Local Working Groups (LWGs) to ensure state priorities are being addressed locally. Source water protection concerns continue to be an important part of the discussion, although they are not likely to be fully addressed without water utility expertise at the table. Members of these

[1]Those in U.S. territories and associated states should contact the nearest NRCS office to determine who can assist them. As an example, the Hawaii NRCS state office also covers American Samoa, Guam, the Northern Mariana Islands, the Republic of Palau, the Federated States of Micronesia, and the Republic of Marshall Islands.

committees are from a wide variety of natural resource and agricultural interests, including representatives from federal and state natural resource agencies and agricultural and environmental organizations. Although many of the committee's members are federal and state agencies associated with agriculture (Farm Service Agency, U.S. Forest Service, etc.), there are membership categories for others who have knowledge and interest in conservation programs and their impacts. Therefore, utilities seeking to participate as members of the State Technical Committee may submit requests to the state conservationist explaining their interests and relevant credentials. Even if utilities are not able to commit to serving on the committee, committee meetings are open to the public. The state conservationist must provide public notice of meetings and allow attendance and comment. Methods of receiving this information vary locally. Interested utilities should contact their state conservationist and ask to be added to any notices.

Summary of NRCS Programs

The table below provides a summary of the NRCS programs that benefit source water protection.

Natural Resources Conservation Service Programs

Conservation Programs with Utility Partnership Opportunities	Conservation Programs for Farmers and Ranchers	Forestry Programs
Regional Conservation Partnership Program (RCPP) Entities partner with producers to address soil, water, wildlife, and related natural resource concerns on regional or watershed scales.	**Environmental Quality Incentives Program (EQIP)** Provides financial and technical assistance to agricultural producers to implement practices that improve natural resources and help producers meet environmental regulations. EQIP includes some funding and technical assistance for producers to monitor their edge-of-field runoff water quality.	**Healthy Forests Reserve Program (HFRP)** Provides payments to landowners to assist them in restoring and protecting forestland resources on private lands through permanent and 30-year easements, contracts and cost-share agreements.
Conservation Innovation Grants (CIG) Funds development of the tools, technologies, and strategies to support next-generation conservation efforts.	**Conservation Stewardship Program (CSP)** Helps producers implement management activities beyond the minimum conservation practice standard requirements.	**Joint Chief's Landscape Restoration Partnership** Improves the health of forests where public forests and grasslands connect to privately owned lands.
National Water Quality Initiative (NWQI) Works with landowners to implement conservation practices in priority watersheds to increase water quality.	**Conservation Reserve Program (CRP)** Provides financial compensation for landowners to voluntarily remove land from agricultural production for an extended period to benefit soil, water quality and wildlife. Run by Farm Service Agency with NRCS technical support.	**Forest Legacy Program** Provides grants to State partners to protect important forests by providing forest products and resource-based jobs and protecting air and water quality.
NRCS Water Quality Landscape Initiatives Uses Landscape Conservation Initiatives to accelerate the benefits of voluntary conservation programs, such as cleaner water and air.	**Agriculture Conservation Easement Program (ACEP)** Used to purchase agricultural land easements or to restore, protect, and enhance wetlands using 30-year or permanent easements.	
Edge-of-Field Monitoring Offers funding to assist in monitoring water quality at the edge of producer's fields to gauge effectiveness of conservation practices.	**PL-566 Watershed Protection and Flood Prevention Program** Installs watershed protection and improvement projects that create and protect vital infrastructure while conserving and protecting natural resources.	
	Small Watershed Rehabilitation Program Repairs, updates, and improves the longevity of the small flood control dams reaching the end of their designed lives.	

Conservation Districts

Conservation districts are known by several names, such as soil and water conservation districts, natural resources districts, and resource conservation districts, and they are organized in a variety of different ways based on local needs. They are unique local units of state government that use state, federal, and private sector resources to solve today's conservation problems.

The guiding philosophy of conservation districts is that decisions on conservation issues should be made at the local level, by local people, with technical assistance provided by USDA. These local "boots on the ground" professionals can work with many stakeholders to address natural resource concerns. Created to serve as stewards of natural resources, conservation districts take an ecosystem approach to conservation and protection. Conservation districts provide conservation programs and services, and they also link landowners and managers to other available programs and opportunities. They continually scan the needs of their local communities, working in partnership with others involved in conservation to set local priorities, develop action plans, and engage in opportunities to address natural resource issues.

These efforts provide citizens with a community access point on natural resource issues and allow them to assist in managing private lands for a cleaner, healthier country. Utilities can benefit from a good relationship with their local conservation district(s) by identifying partners, coordinating actions, and knowing a trusted source that can reach out to the agricultural community.

To find the conservation district that serves your source water area, contact the National Association of Conservation Districts' Conservation District Directory.

Case Studies

Projects already under way or completed

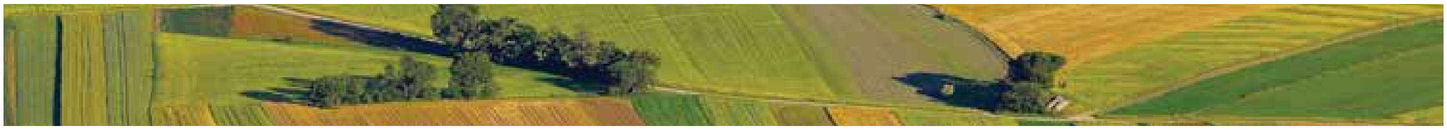
Cedar Rapids, Iowa

Cedar Rapids is participating in the Middle Cedar Partnership Project. This Regional Conservation Partnership Program (RCPP) project focuses on several sub-watersheds within the city's source water area. The project involves 17 partners, including the agricultural community (directly with producers and through organizations such as the Iowa Farm Bureau and the Iowa Soybean Association), several local conservation districts, and others. This project will make $4.3 million available from 2015-2020, with three objectives:

1. Develop watershed plans to target agricultural best management practices (BMPs) for the greatest source water protection benefit.
2. Provide assistance to implement these BMPs, with an emphasis on reducing nitrate loads.
3. Conduct outreach to help spread the word and foster implementation of these and other BMPs.

Beaver Water District, Arkansas

Beaver Water District (BWD) in Northwest Arkansas has worked with partners to form the West Fork White River Watershed Project. Involving 13 partners, this project is garnering more than $8.5 million for conservation practices to protect source waters from 2016-2021. BWD is contributing just over $1 million, with its investment leveraged nearly nine times. This project is using the PL-566 program and EQIP to reduce erosion and improve incoming water quality. Expected outcomes include 1-2 miles of stream restoration, 2-4 miles of riparian zone restoration and enhancement, about 150 farm conservation plans and the installation and deployment of 300 conservation practices. The source water goals are the reduction of both sediment and nutrients.



Projects getting under way in 2018

Through late 2016 and 2017, AWWA provided technical assistance to several RCPP proposals. These project ideas were found through an extensive outreach program that surveyed AWWA utility members and followed up on dozens of potential projects. Ultimately, three RCPP proposals were submitted and all three were selected for funding. These three projects are described in the following sections:

Mills River Source Water Protection

Utilities Benefitting: Water utilities in cities of Hendersonville and Asheville, North Carolina
Project Value: $1.5 million (including match)

The goal of this project is to help protect the source water for 85,000 people in the North Carolina cities of Hendersonville and Asheville, as well as surrounding counties that depend on the Mills River for drinking water.

The primary objectives for this multi-benefit project are restoring streambanks, reducing sediments and nutrients, and providing for the safe mixing of agri-chemicals. However, it will also improve degraded fish and wildlife habitat, help ensure future agricultural productivity, foster locally produced foods, and expand a unique on-farm educational forum promoting sustainable agricultural practices.

The project will occur on the main stem of the Mills River and on Foster Creek, a direct tributary. Both are located in Henderson County, North Carolina. The Mills River lies mainly within the Pisgah National Forest, and in the upper reaches, the river is in very good condition. The lower 30 percent of the watershed, however, is impaired.

Years of farming, clearing, and straightening area streams has left the Mills River and its tributaries with nearly vertical banks and confined to narrow channels in areas where meanders were historically located. The result is scouring, extreme streambank erosion, steep dangerous banks that are unstable and constantly sloughing, and high sediment loading.

The resultant sedimentation severely impairs the source water for 85,000 people downstream and results in excessive treatment costs that fall disproportionately on low-income populations. In addition, there is a critical need to provide areas where agri-chemicals can be safely mixed without the risk of accidental spills into source waters.

To address these issues, a mile-long stretch in the Foster Creek tributary will undergo complete streambank restoration, and a second area, along the main stem of the Mills River, will see the construction of an agrichemical handling facility. Other project activities will involve cattle operations where bank sloping, riparian fencing, and off-channel watering tanks will be implemented.

Otter Lake Source Water Protection Effort

Utility Benefitting: Otter Lake Water Commission
Project Value: $1.7 million (including match)

Otter Lake lies in the heart of Illinois corn and soybean country about 20 miles southwest of Springfield. The 765-acre lake is superb for recreation, but its primary importance is that it provides drinking water for 14,500 rural residents in six towns, two villages, and two rural water districts.

The Otter Lake project aims to protect the source water for the people who depend on the lake, and to do so in a manner that improves both the environment and the agricultural producers' bottom line.

The lake's watershed spans 13,000 acres, with agriculture making up 77% of the watershed. Approximately 25% of all soils in the watershed can be classified as highly erodible, with most erosion occurring on slopes adjacent to or within a short distance of the lake.

Otter Lake has experienced excessive levels of sedimentation and nutrient loading. Nutrient-induced cyanobacterial blooms have occurred in the past, and the lake is currently impaired by phosphorus. Nitrogen is now an elevated concern due to the rapid expansion of tile drainage that has occurred over the past few years.

The key innovation in this project is that work will occur on areas that have resource concerns, and which also produce negative returns for farmers. The project partners will pre-identify sites where conservation is needed. Then, working with producers, the partners will use a high-tech precision conservation tool to further identify areas of opportunity. In effect, the partners will micro-target areas within a farmer's field that have both resource concerns and negative returns on investment.

Applying the most effective conservation practices to the identified areas will provide not only the largest return for each conservation dollar invested, but will also assist the farmer in maintaining economic health.

Milford Lake Watershed RCPP Project

Utilities: Kansas River Water Assurance District No. 1. The district is comprised of the following water utilities: Manhattan, Topeka, Lawrence, Olathe, and Water One Project Value: >$8 million (including match)

Milford Lake at the lower end of the Republican River Basin in Kansas is a U.S. Army Corps of Engineers reservoir with approximately 15,700 surface acres and 163 miles of shoreline, making it the largest lake in Kansas. Federally authorized uses of Milford Lake include flood control, water supply, water quality, navigation, recreation, and wildlife. Milford Lake contributes to source drinking water for about 800,000 people in Kansas along the Kansas River and provides habitat for many types of aquatic and terrestrial wildlife. In recent years, Milford Lake's ability to serve as a reliable water source and as excellent wildlife habitat has been negatively impacted by the annual formation of harmful algal blooms (HAB) within the lake.

The frequency of HABs within Milford Lake has created a heightened sense of concern among lake stakeholders. The blooms could adversely impact potable water supplies, wildlife, and water-based recreation.

This project serves as one of the largest conservation efforts undertaken within the Milford Lake Watershed. It will bring together partners to work with NRCS on implementation of conservation practices that will reduce the amount of nutrients entering Milford Lake. A reduction in nutrients should decrease the occurrence of HABs.

Conclusions and Key Takeaways

While there are many opportunities to leverage federal programs to protect drinking water, utilities should remember at least three key points:

1. Agricultural programs through the USDA offer a vehicle for water utilities to get involved in farm conservation to help protect source waters. Get involved!

2. Each state conservationist is a professional dedicated to making conservation projects happen and should be the first call for putting a project together.

3. Be aware of the Regional Conservation Partnership Program, Conservation Innovation Grants, the National Water Quality Initiative, and the Water Quality Landscapes Initiatives for potential partnership opportunities.

AWWA is heavily invested in expanding utility partnerships with agriculture through these programs. At the time of this publication, AWWA was working with members of U.S. Congress and other partners on the reauthorization of the 2018 farm bill, looking primarily at the conservation title (which funds the NRCS programs discussed in this document). To support source water protection, we seek the following goals:

1. Emphasize the importance of protecting sources of potable water.

2. Authorize the Secretary of Agriculture to work with drinking water utilities and State Technical Committees to identify local priority areas in each state.

3. Provide additional cost share and incentives for practices that have significant downstream water quality/quantity benefits but little on-farm benefit.

4. Target 10% of Conservation Title funds to protecting sources of potable water.

If enacted, these principles would greatly enhance the conservation program's focus on protecting sources of drinking water and provide many opportunities for water utilities to get involved. You can learn more from this whiteboard explainer video and Op-Ed from AWWA CEO David LaFrance. Several resources are also available from the Source Water Collaborative, including a webinar discussing case studies and a collaborative toolkit for working with agriculture. Working together, the agricultural sector, water utilities, and other partners can build effective partnerships and implement projects to improve source water protection. As the farm bill is reauthorized every few years, AWWA will continue to work for measures that encourage smart, collaborative practices that protect drinking water.

Appendix A: Additional information on individual USDA programs

USDA Conservation Programs (Partnership Opportunities for Utilities)

While the vast majority of NRCS conservation program dollars and technical assistance must go directly to farmers, ranchers, and other agricultural producers to implement specific practices, there are several programs in which utilities may directly participate. Even for the programs focused directly on agricultural producers, utilities can be beneficiaries of water quality improvements from the efforts. Utilities should reach out to their state conservationist's office to get involved in local programs.

Regional Conservation Partnership Program (RCPP)

The Regional Conservation Partnership Program (RCPP) creates partnership opportunities for utilities to target and leverage federal conservation funding for specific areas and resource concerns. Water utilities are specifically mentioned as an eligible partner and Congress expressly intended for water utilities to participate.

In the first years after RCPP was authorized in the 2014 farm bill, the program has provided approximately $250 million annually in funding to address specific natural resource concerns in selected project areas. It's difficult to predict how much funding will be available and when it will be issued. For example, leading up to a year in which the farm bill is being reauthorized, it's unlikely that NRCS will take applications until after the funding for the following year is determined. Therefore, utilities would benefit from working with partners as soon as possible to identify possible projects well before the issuance of an RCPP application period and get ready to propose them when funding becomes available. Utilities can be notified of RCPP application periods by signing up for NRCS press releases and/or by staying in close contact with agricultural partners, their state conservationist's office, and local conservation districts.

Project areas for RCPP projects are defined by eligible partners and are selected through a state or national competition. In addition to defining the project's geographic area, providing assistance, and possibly acting on behalf of the producers within the project area, partners must also provide a significant portion of the overall funding of the project. This leverages the partner's state, local, or private funding with RCPP's federal funding. These matching funds include cash contributions and in-kind contributions of time spent by employees providing their expertise and technical assistance to the partnership, monitoring, and other activities readily available at the utility. There is no specific match amount required, but most successful proposals have leveraged at least one local dollar (combined cash and in-kind from all partners) for every federal dollar invested.

What kinds of projects are eligible. USDA's publication "Partner-led Solutions" describes eligible project types, indicating that the program "works with producers to implement the right conservation practices in the right places to have the largest returns. Some of these practices include planting cover crops, limiting tillage, establishing buffer strips, and managing nutrient use." Innovative practices to improve water quality from agricultural areas are encouraged through the program, such as the Minnesota Agricultural Water Quality Certification Program, which has promoted nutrient management and other practices and is credited with keeping millions of pounds of sediment out of area rivers and reducing phosphorus application by thousands of pounds.

Several RCPP projects have included utility involvement as discussed in the included case studies. In essence, RCPP allows partnerships to target USDA funds through existing mechanisms (such as EQIP, discussed below) when combined with actions by the partners that help to achieve those goals. Extensive documentation is available for the activities that can be undertaken within each program; the state conservationist's office can guide utilities through questions on these programs. Project awards have generally been capped at $10 million from USDA funding and are required to be completed within five years.

How to apply. Although the dates vary, over the past few years, funding for RCPP has generally been announced each year early in the year, with preproposals due in the spring. The exception has been in years where NRCS has not yet been allocated funding for the following year (such as 2018 because the farm bill covering 2019 spending had not yet been passed), during which the timing can be unpredictable. Accepted preproposals will have a few months to provide additional information, and notification of selection generally takes place by the end of the year for funding in the following year (for example, preproposals due in spring 2017 were to fund projects beginning in 2018). If your utility is interested in pursuing an RCPP proposal, the first contacts should be to the state conservationist, the local NRCS office, and your local conservation district. They can help you determine if any given project idea would be appropriate for RCPP. Additionally, any leaders in your area on conservation (nonprofits, agricultural organizations, state/local watershed programs, etc.) can help find partners or be partners themselves. Many of the successful RCPP projects identified partners well in advance of the opening of the application period.

Conservation Innovation Grants

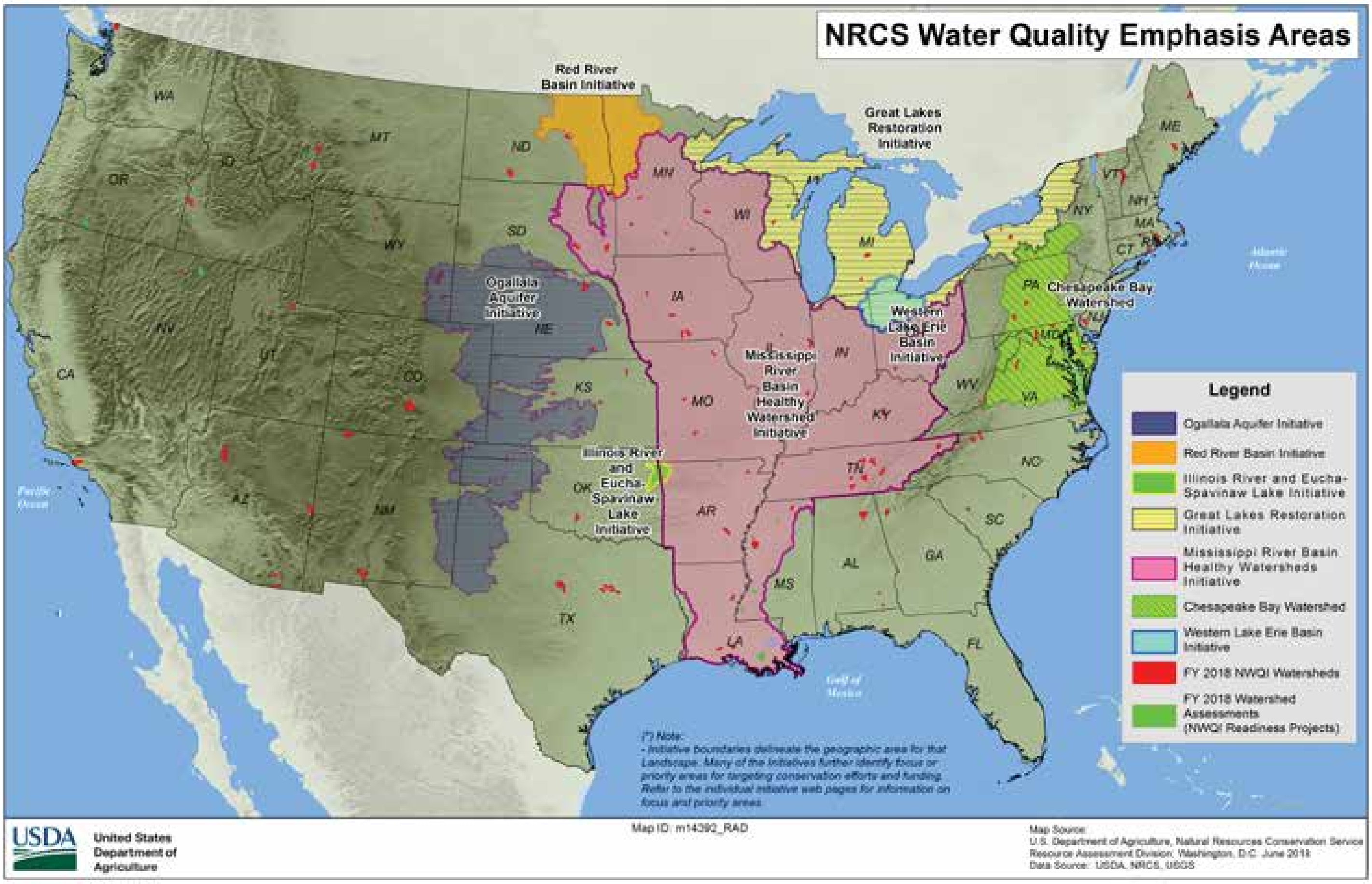
Conservation Innovation Grants (CIG) are competitive grants that stimulate the development and adoption of innovative approaches and technologies for conservation on agricultural lands. CIG uses Environmental Quality Incentives Program (EQIP) funds to award competitive grants to nonfederal governmental or nongovernmental organizations. Through CIG, NRCS partners with public and private entities to accelerate technology transfer and adopt promising technologies. These new technologies and approaches address some of the nation's most pressing natural resources concerns. CIG benefits agricultural producers by providing more options for environmental enhancement and compliance with federal, state, and local regulations. Innovative methods for protecting source waters could potentially qualify for CIG funding.

How to apply. A CIG funding notice is announced each year, and in some years, more than one round of funding is provided. Funds for single- or multi-year projects, not to exceed three years, will be awarded through a nationwide competitive grants process. Projects may be watershed-based, regional, multi-state ,or nationwide in scope. The natural resource concerns eligible for funding through CIG will be identified in the funding announcement and may change annually to focus on new and emerging, high priority natural resource concerns. Much like with RCPP, utilities can stay informed by signing up for press releases and keeping in close contact with partners and can increase their chances of success by organizing the ideas prior to the application period. In recent years, funding has consisted of $10-20 million per year, with a cap for a single project around $2 million for the federal share. Some states also have smaller state CIG project pools.

National Water Quality Initiative

Through the National Water Quality Initiative (NWQI), NRCS and partners work with producers and landowners to implement voluntary conservation practices that improve water quality in high-priority watersheds. NRCS works closely with conservation partners to select priority watersheds where on-farm conservation investments will deliver the greatest water quality improvements. NWQI is designed to help individual agricultural producers take actions to reduce the introduction of sediment, nutrients, and pathogens into waterways where water quality is a critical concern. The goal of NWQI is to implement conservation practices in sufficient quantity in a concentrated area so that agriculture no longer contributes to the impairment of water bodies within these priority watersheds.

How to engage. NRCS will continue to coordinate with local and state agencies, conservation districts, nongovernmental organizations, and others to implement this initiative. Partners will play a crucial role in encouraging and supporting producer participation. Partners can also work with state conservationists to identify specific watersheds to target.



NRCS Water Quality Landscape Initiatives

NRCS uses Landscape Conservation Initiatives to accelerate the benefits of voluntary conservation programs, such as cleaner water and air, healthier soil, and enhanced wildlife habitat. NRCS conservation programs help agricultural producers improve the environment while maintaining a vibrant agricultural sector. These initiatives enhance the locally driven process to better address nationally and regionally important conservation goals that transcend localities. They build on locally led efforts and partnerships and are built on scientific information. Through the initiatives, NRCS and its partners coordinate the delivery of assistance where it can have the most impact. Where applicable, NRCS works with regulators to help producers get predictability for their use of voluntary conservation systems or practices, giving them peace of mind that they can sustain agricultural production in the future.

Examples of Water Quality Emphasis Areas

- Chesapeake Bay Watershed Initiative
- Ogallala Aquifer Initiative
- Great Lakes Restoration Initiative
- Mississippi River Basin Healthy Watersheds Initiative

How to engage. NRCS collaborates with local conservation districts, state environmental agencies, land grant universities, and others to select focus areas and other opportunities for conservation projects.

Edge-of-Field Monitoring (EOFM)

As part of the Environmental Quality Incentives Program, NRCS offers funding to farmers and ranchers to monitor their edge-of-field runoff water quality. The objectives of NRCS EOFM are to 1) evaluate conservation system effectiveness in reducing nutrient and sediment impacts to surface water; 2) validate and calibrate models; and 3) inform on-farm adaptive management. When combined with instream monitoring, NRCS EOFM can be an important piece in understanding nutrient and sediment movement within a watershed.

How to engage. Each year, NRCS offers funding for EOFM to landowners in select watersheds who then partner with a monitoring professional to implement monitoring, analyze data, and evaluate the effectiveness of conservation practices on a particular field. Opportunities exist for utilities to work with the landowner as a monitoring partner, a convener, or additional funding source to establish which conservation practices are most protective of water quality in a watershed. Utilities can stay informed by signing up for press releases and contacting their State Conservationist to indicate interest.

USDA Conservation Programs for Farmers and Ranchers

As previously mentioned, most NRCS conservation programs are specifically designed for farmers, ranchers, and other agricultural producers and do not have a direct connection to utilities. Nevertheless, they can play a major role in improving quality in source waters. Participation with state technical committees, local soil and water conservation districts, and other stakeholder networks can illuminate how to implement these programs. Many of these programs are also tools available as components of RCPP projects.

Environmental Quality Incentives Program (EQIP)

EQIP provides financial and technical assistance to producers and landowners to plan and install structural, vegetative, and land management practices on eligible lands to alleviate natural resource problems. Eligible producers enter into contracts to receive payment for a portion of the cost of implementing conservation practices. Approved activities are performed according to an EQIP plan – developed in conjunction with the agricultural producer – which identifies the appropriate conservation practice(s) to address resource concerns on the land.

Conservation Stewardship Program (CSP)

CSP provides financial and technical assistance to producers to maintain and improve existing conservation systems and adopt additional conservation activities. Under CSP, participants must meet a stewardship threshold for a set number of priority resource concerns when they apply for the program, and then must agree to meet or exceed the stewardship threshold for additional priority resource concerns by the end of the five-year contract. In exchange, participants receive annual payments that are based, in part, on conservation performance.

Conservation Reserve Program (CRP)

CRP is the largest federal, private-land retirement program in the United States, spending more than $2 billion annually. The program provides financial compensation for landowners (annual rental rate) to voluntarily remove land from agricultural production for an extended period (typically 10 to 15 years) for the benefit of soil and water quality improvement and wildlife habitat. This program is run by the Farm Service Agency, with technical assistance by NRCS.

Agriculture Conservation Easement Program (ACEP)

ACEP is comprised of two main components: The Agricultural Land Easement (ALE) and Wetland Reserve Easement Program (WREP). ALE requires USDA to enter into partnership agreements with eligible entities to purchase agricultural land easements. The entities agree to share the cost of the easement, purchase easements according to USDA's requirements and enforce and monitor easements purchased. Agricultural land easements allow production to continue on the land while prohibiting nonagricultural uses.

WREP funds are used to restore, protect, and enhance wetlands using 30-year or permanent easements. Landowners who have owned the land for at least 24 months prior to enrollment may submit an offer to USDA that will be evaluated based on its conservation benefits, cost effectiveness, and financial leverage. If selected, the landowner agrees to restore and maintain the wetland according to an approved wetland reserve easement plan. USDA, in return, provides technical and financial assistance for wetland restoration and compensation based on the easement or contract.

PL-566 Watershed Protection and Flood Prevention Program

The Watershed Program established through the Watershed Protection and Flood Prevention Act of 1954, as amended (Public Law 83-566) (Watershed Program) authorizes NRCS to work with local sponsors to install watershed protection and improvement projects. These projects create and protect vital infrastructure while conserving and protecting natural resources and contributing to local economies.

Small Watershed Rehabilitation Program

With many of the nation's 11,000 small flood control dams reaching the end of their designed lives, this program provided $250 million to repair, update, and improve the longevity of the structures.

Forestry Programs

Healthy Forests Reserve Program (HFRP)

The HFRP provides payments to landowners to assist them in restoring, enhancing, and protecting forestland resources on private lands through permanent and 30-year easements, 30-year contracts, and 10-year cost-share agreements. Eligible landowners agree to implement restoration plans. In addition, landowners may avoid certain regulatory restrictions under the Endangered Species Act on the use of that land.

Joint Chiefs' Landscape Restoration Partnership

The U.S. Forest Service and USDA's NRCS are working together to improve the health of forests where public forests and grasslands connect to privately owned lands. Through the Joint Chiefs' Landscape Restoration Partnership, the two USDA agencies are restoring landscapes, reducing wildfire threats to communities and landowners, protecting water quality and enhancing wildlife habitat. The partnership began in 2014, and each year the agency selects new three-year projects.

Forest Legacy Program

Through the Forest Legacy Program (FLP), the Forest Service provides grants to State partners to protect important forests (e.g., those providing forest products and resource-based jobs, protecting air and water quality, providing recreational opportunities, and protecting important fish and wildlife habitat). Projects are selected through a two-step competitive process resulting in high quality projects that are supported locally and are nationally significant. Projects are evaluated for importance (includes ecologic and environmental criteria), threat, and strategic contribution. The states identify priority areas within the state to target FLP. Lands are protected through conservation easements or fee-simple purchases to be held by state agencies or other units of government.

American Water Works Association

APPENDIX J

Maintenance and Application Records

- Records to be kept by field:
  - Soil test reports
  - Date(s) of manure/wastewater application(s)
  - Source and rate of manure/wastewater applied
  - Date and rate(s) of other nutrients applied
  - Method of application (e.g., surface applied, injected, incorporated, irrigated)
  - Acres used and area of field applied on
  - Weather conditions during application
  - Field conditions during application of manure (wet, dry, frozen, etc.)
  - N-credit from previous year's manure application
  - Previous crops grown and yields
  - Recommended nutrient application rates, including procedures used to determine
  - Plant tissue sampling and testing reports (where applicable)
  - Pre-Sidedress Nitrate Test (PSNT) reports (where applicable)
- Other records:
  - Manure/wastewater quantities produced and nutrient analysis results
  - Inspection and maintenance records
  - Agreements for application of manure/wastewater on land not owned by the producer
  - Record of manure/wastewater sold or given away to other landowners
  - Location of drainage tile vents, streams, etc. with respect to spreading areas

Inputs to Animals

Describe the formulation and management of animal diets Ideally, this should result in:

- Optimum production and/or animal health
- Best economical use of feed materials
- Reduced nutrient excess
- Minimized amount of (excreted) nutrients contained in manure

Alternative Utilization Activities (where applicable)

- Transport and off-site utilization
- Power generation (e.g., methane production, combustion for energy)
- Conversion to value-added products (e.g., compost, energy)

Inspections, Operation & Maintenance, Training

- Schedule used for inspection of structural and vegetative practices and equipment
- Operational and maintenance activities planned
- Schedule for review of animal production management practices/activities by a qualified third party to ensure proper implementation of CNMP
- Specific plans for training farm employees how to follow CNMP, including when training will be provided, such as procedures for:
  - New employees
  - New processes, procedures or equipment
  - Employee responsibilities

Schedule of CNMP Implementation

- Plans for annual review and update of the CNMP
- New components that are planned and the implementation scheduled for each component
- Plan for addressing water quality concerns identified in the plan

Emergency Action Plan

- Actions to take in the event of a spill, discharge or failure of a collection, storage, treatment of transfer component
- Telephone numbers to report and seek assistance in the event of an emergency
- Show anticipated flow paths in the event of a spill, discharge or failure on a site map
- Plan should be readily available to all employees

References and Appendices

- Any publications or sources used for calculations or decisions made in the CNMP. Crop advisors, engineers, and nutritionists, as well as some private business and agricultural agencies, may be certified to assist in writing and developing a CNMP.

About this Publication

This publication was funded by USDA Special Needs, Purdue University, and Michigan State University.

It was adapted in part from the Livestock and Poultry Environmental Stewardship project funded by the U.S. EPA, coordinated by the University of Nebraska-Lincoln, and published by the MidWest Plan Service, 122 Davidson Hall, Iowa State University, Ames, Iowa 50011-3080 and from "Developing a Comprehensive Nutrient Management Plan (CNMP) (published by the Michigan Agriculture Environmental Assurance Porgram, Fall 2001). See <www.lpes.org> or <www.maeap.org> or call (800/562-3618) to obtain access to this and other lessons.

Publications in this series:

- Land Application Records and Sampling
- Emergency Action Planning for Livestock Operations
- Mortality Management
- Inspecting Your Confined Feeding Operation
- Feeding Strategies to Lower N&P in Manure
- Building Good Neighbor Relationships
- Disposal of Farm Medical Wastes
- Manure Nutrient Recycling
- Environmentally Sensitive Field Characteristics
- Manure Applicator Calibration
- Odor Control Options for Confined Feeding
- Comprehensive Nutrient Management Plans

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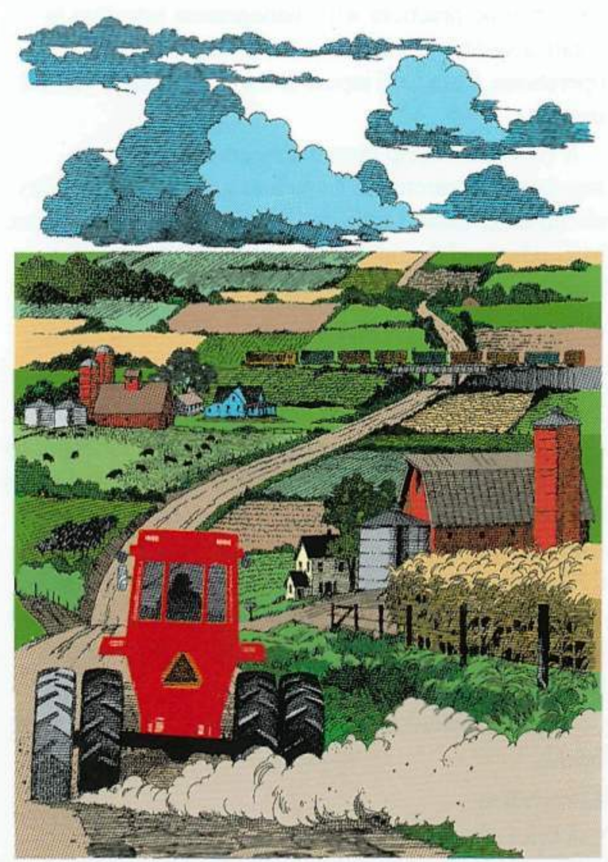
E-2819

Best Environmental Management Practices

Farm Animal Production

Comprehensive Nutrient Management Plans (CNMP)

Don Jones, Al Sutton, Purdue University, and Charles Gould, Michigan State University



Best Environmental Management Practices

Farm Animal Production

Comprehensive Nutrient Management Plans (CNMP)

Don Jones, Alan Sutton, Purdue University, and Charles Gould, Michigan State University

What is a CNMP?

A Comprehensive Nutrient Management Plan (CNMP) is a total planning tool that details the animal production related activities for a specific farming operation. A CNMP describes a farm's production practices, as well as the equipment and structure(s) used. It combines conservation practices with management activities to create a system that addresses animal production operations, from feed inputs to the utilization of animal manure.

A CNMP can help farm managers comply with regulatory requirements as well as protect water quality, obtain more benefit from the animal manure and organic by-products of the operation, and minimize negative impacts to the environment and public health.

CNMP Components

A CNMP is a confidential document that allows livestock producers to develop a custom plan for the operation while complying with regulatory guidelines by addressing items such as manure management, field crop nutrients, and storm water runoff in a coordinated manner. Producers evaluate their whole farm through a CNMP, taking a comprehensive look at their entire operation. Producers can confidently make management decisions tailor-made for the operation with a well-documented plan in place.

A CNMP includes a number of components, detailed below.

Overview

- A brief statement describing the overall farm operation, including enterprises, goals, and long-term plans for resource management.

Farm Headquarters Map

A site map showing the location of farm buildings, animal housing, manure storage structures, other sources of manure and wastewater, feed storage, farm house(s) and any other relevant physical features.

Production

- Species, weight, production level, etc. of livestock (herd/flock inventory)
- Amount, location and characteristics of all wastewater generated and any existing water control devices:
  - Manure and wastewater nutrient content and volume
  - Milkhouse and parlor wastewater
  - Water from milk plate coolers/ supplemental cooling systems
  - Runoff from feedlot/barnyard and stored manure areas
  - Leachate from silage storages
- Animal mortalities management - i.e., compost, render, burial, incineration, etc.
- Veterinary waste management
- Volume of stored manure

Manure Collection

- Manure and wastewater collection method(s)
- Location of manure collection points
- Schedule of manure collection
- Equipment and/or structural facilities used for collection

Manure Storage

- Type, location and size (dimensions) of storage facility(s)
- Storage capacity:
  - Volume
  - Storage time available
- Site suitability for storage (existing and planned)
- Method of measuring freeboard, where applicable, for storage

Manure Transfer

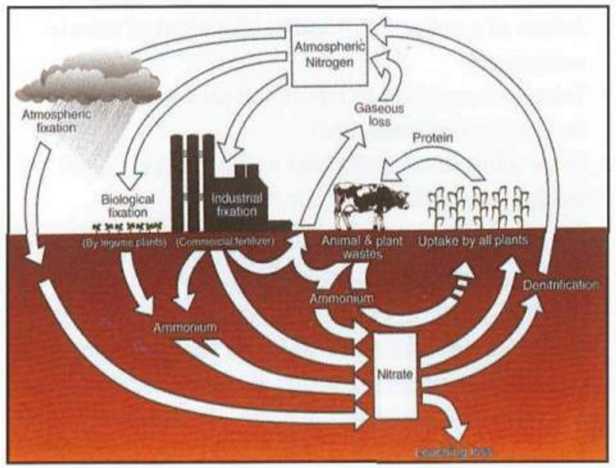
- Method, frequency/schedule, structures, and equipment used for the movement of manure and wastewater between collection, storage, and utilization locations.

Manure Treatment (where applicable)

- Type, function, capacity and location of any treatment facility or equipment

Conservation Practices in Manure Application Areas

- Evaluation of potential for nitrogen or phosphorus transport to surface and/or ground water. Provide a complete description of the following:
  - Soil in application areas
    - Soil hydrologic group
    - Soil management group
    - Percent slope
    - Topography
    - Soil test P value (Bray P1 in lbs/ac)
    - Nitrogen leaching index for soil hydrologic group
  - Water quality issues
    - Location of concentrated runoff flows or surface inlets to tile lines
    - Location of risers and outlets and monitoring outlets during and after manure application
    - Setback requirements from surface water, wells, etc.
    - Divert clean runoff from upslope areas and roof gutters to reduce the volume of contaminated material
  - Surface cover in application areas
    - Residue cover/cover crops
    - Vegetative buffer width available



- Crop and soil needs for manure nutrient application
  - Manure P application rates
  - Manure N application rates
  - Manure K application rates
  - Manure application method(s)
- Sensitive areas near application areas (sinkholes, streams, water bodies, wells, gullies/swales, tile inlets, drinking water sources, property boundaries, etc.)
- Conservation and management practices used for soil erosion control and drainage to control offsite transport of N, P, and other contaminants
- Maps of each field, showing sensitive areas, setbacks, and locations of specific practices/activities, and the areas where manure will be applied

Land Application Management

- Nutrient budget for nitrogen, phosphorus, and potassium from all sources (include form, source, amount, timing and method of application)
- Calibration procedures for equipment
- Application schedule (estimated dates)
- N, P and K levels in the manure to be applied. Take samples from storage at the time of application, and account for losses due to method of application used.
- Manure application rates, for each field, based on:
  - Crops to be grown
  - Realistic crop yield goals
  - Crop nutrient needs
  - Soil test results (within last three years)
  - Previous year's crops and manure application to estimate N nutrient credits
  - Manure and wastewater nutrient content
  - Is N or P the limiting nutrient
  - Winter spreading may require special provisions to control runoff. Check state requirements for applying manure on frozen or snow-covered areas
- At the time of application, consider field-specific conditions (wet, dry, frozen, etc.) and adjust application rates accordingly
- P build-up or removal, acres of land needed for sustainablility

Comprehensive Nutrient Management Plan

For

____
(Name)

____
(location)

By

____
(Name of Preparer)

Natural Resources Conservation Service

____
(Date)

COMPREHENSIVE NUTRIENT MANAGEMENT PLAN (CNMP)
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Application Equipment Calibration (*date)*
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Other Utilization Options (*composting, etc - if needed)*

SECTION 8
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Soil Testing Procedure
Manure Analysis Procedure
Application Equipment Calibration

SECTION 1
CNMP Purpose and Conditions

PURPOSE OF THE CNMP:

The **Comprehensive Nutrient Management Plan (CNMP)** is a conservation system for your animal feeding operation. It is designed to address, at a minimum, the soil erosion and water quality concerns of your operation. The CNMP encompasses the storage and handling of the manure as well as the utilization and application of the manure nutrients on the land.

Manure and Nutrient Management involves managing the source, rate, form, timing, and placement of nutrients. The practice of nutrient management serves four major functions:

1. Supply essential nutrients to soils for plant utilization to produce adequate food, forage, and fiber.
2. Provide for efficient and effective use of scarce nutrient resources so they are not wasted.
3. Help maintain or improve the physical, chemical, and biological condition of the soil.
4. Minimize environmental degradation caused by excess nutrients in the environment.

NITROGEN AND PHOSPHORUS vs. WATER QUALITY:

The two major nutrients of concern are phosphorus and nitrogen because they can impact water quality, human health, and animal health. Nitrogen as nitrate is water soluble and has the potential to leach into ground water supplies. Nitrogen rich drinking water has potential health impacts to small babies and to adults if consumed in high quantities. Surface applied nitrogen, that isn't incorporated, can be lost to the atmosphere as gaseous ammonia nitrogen and nitrous oxide. Not only does this loss reduce available crop nutrients but nitrous oxide is a gas that contributes to the greenhouse effect. Ammonia volatilized to the atmosphere is also a component of nitrogen-enriched rain, which effects many things. Ammonia can also be harmful to aquatic life if it becomes concentrated in levels of 0.02mg/L or greater.

Phosphorus is a concern because when it gets into surface water bodies it can cause explosive algae blooms and eutrophication in the water body. This can lead to depressed oxygen levels and fish kills. Phosphorus is often the limiting nutrient for plants in water bodies, so when it becomes readily available, plants like algae, thrive and algae blooms result.

The primary way phosphorus can get into water bodies is through runoff and erosion. This is especially true if excess phosphorus is surface applied, as either manure or commercial fertilizer, or if heavy rains occur just after spreading. Phosphorus can get into water bodies through erosion because phosphorus tends to attach to soil particles and move with them. Controlling erosion through erosion control practices, therefore not only keeps soil in place but also limits the amount of phosphorus lost to the environment, keeping it available for crop needs. Controlling erosion is also important since phosphorus tends to accumulate in the soil from one year to the next. Only 80% of the phosphorus that is in manure is available to the current crop and the remaining 20% stays in the soil. This reserve increases each year that spreading continues at excessive rates if this reserve is not accounted for with a soil test. Phosphorus can also get into surface water by being carried in solution as soluble phosphorus. This soluble form is highly bioavailable and can contribute significantly to eutrophication even at low levels.

CONDITIONS:

The State of New Hampshire DES Water Quality Regulations requires pollutants (manure, milkhouse waste, silo drainage, non-point sources of pollution, etc.) to be managed so as not to enter the waters of the State. Your CNMP provides the basic information on how the wastes produced from your operation, and/or applied on your fields, will be utilized. Following your CNMP will keep you in compliance with the State Water Quality Regulations.

NOTE: If the number of livestock change (10% or more), your fields change, your soil test results change significantly upwards, your rotation changes, the method of storage changes, or if the method of application needs to change, contact the NRCS/SWCD office to get this plan revised.

Sample Farm

BASIC FARM INFORMATION

<u>Farm Operator Information:</u>
Name:
Address:

County:
Phone:
E-mail:

<u>Farm Description and Purpose:</u>

<u>Goals:</u>

1. Maintain and improve the economic return from the dairy operation.
2. To apply dairy manure to obtain maximum nutrient benefit while minimizing runoff of nutrients.
3. To control erosion on the crop fields
4. To operate the farm in an environmentally and socially acceptable manner.

<u>Future Plans</u>: (anticipated change of more than 15% of land base or greater than a 50 animal unit change on an annualized basis)

<u>Total Acres Cropped:</u>
Corn silage and hay are grown for feed. The best fields are in a hay-corn rotation. A crop rotation schedule is included.

Corn Land:	Owned:	Rented:	Total:
Hay in Rotation:	Owned:	Rented:	Total:
Hay/Legume:	Owned:	Rented:	Total:
Pasture:	Owned:	Rented:	Total:
Other Crops:	Owned:	Rented:	Total:
Total: Acres:	______________	__________	___________

Contacts for rented acreage (names and phone numbers):

Number and Type of Animals:

Animal Type	Number	Ave. Wt.	A.U.	Manure Storage Options
Holsteins milkers				
Breeding heifers and dry cows				
Yearlings				
Young calves				

Total AUs from animals is:

Special Environmental Factors: (i.e. sensitive watersheds, sand/gravel aquifers, bedrock etc.):

Sketch:

Sketch (or enlarged and labeled aerial photo) of farmstead area

Maps:

Attached are copies of aerial photos showing fields, field identification numbers, acreage and sensitive areas. Sensitive areas shown are wells, ponds, streams, waterways, and property boundaries. Field stacking sites for manure are also located on these maps. Soils maps and a legend are also attached.

SECTION 2

COMPREHENSIVE NUTRIENT MANAGEMENT PLAN CERTIFICATION

Farm:____

Location:____

I have received a copy of my Comprehensive Nutrient Management Plan and have had it explained to me. By signing I acknowledge receipt of the plan and confirm my intent to implement it. I also understand that I am responsible for the record keeping and operation and maintenance of this plan.

Landowner/user	Date
Certified Specialist in Manure and Wastewater Handling and Storage	Date
Certified Specialist in Land Treatment Practices	Date
Certified Specialist in Nutrient Management	Date
Certified CNMP Planner	Date

CERTIFICATION OF CONSERVATION PLAN

Farm:____

Location:____

By signing the participant acknowledges receipt of this conservation plan and confirms intent to implement it.

____ ______________

Landuser/owner **Date**

This Conservation Plan meet the requirements of the Field Office Technical Guide

____ ______________

NRCS Certified Conservation Planner Date

Approved By:

____ ______________

Conservation District Date

Schedule of Operations *(may be parts of the Conservation Plan, or include LTP-11 copies here)*

Environmental and Resource Assessments *(may be part of Conservation Plan, or include assessment documentation here from "Nut Mgt Manual Calc worksheets")*

SECTION 3

MANURE PRODUCTION, STORAGE, AND USE:

Numbers and average weight of animals by type, period of confinement and estimated or measured manure production. (*Use NH Manure Screening Tool Spreadsheet printout to document this information or similar manual calculations)*

Manure storage type, volume and length of storage, who designed it, design criteria. (*Use NH Manure Screening Tool Spreadsheet data or AWM software calculations to document the preliminary design for the storage facility)*

Describe Manure Spreaders used and capacities:

Manure to be exported: (amount, to whom, phone number, where it is going)

Waste water volumes produced: (milk room waste, wash water, silage leachate etc.) *(Use NH Manure Screening Tool Spreadsheet data or AWM software calculations to document the preliminary design needs)*

Plan View (Sketch) of Farmstead showing existing and planned components

<u>WASTE STORAGE FACILITY (313) Liquid and Semi-Solid Manure Pit</u>

Operation and Maintenance:

- Maintain the fence around the top of the storage pit.
- Maintain, repair, or replace warning signs as needed.
- Check for cracks or shifting of concrete components when pit is empty.
- Monitor the earth berm surrounding the structure periodically for burrowing animals, noxious and invasive plant species, small trees and shrubs and remove as required.
- Maintain healthy vegetation on the earth berm.
- Repair any bare spots or burrows in the earth berm.
- Waste levels will be monitored during and following unusual storm events.
- As full capacity is approached, enough waste shall be removed at the earliest environmentally safe period to ensure that sufficient capacity is available to accommodate subsequent storm events.
- Waste shall be removed from storage and utilized at locations, times, and rates in accordance with the Nutrient Management (590) developed for this farm.
- After emptying liquid waste and if needed upon inspection, remove the end gate and remove accumulated solids to preserve storage capacity. Reinstall and reseal the endgate.

<u>WASTE STORAGE FACILITY (313) Concrete or Earthern Stacking Pad</u>

Operation and Maintenance:

- Maintain vegetation on the earth berm surrounding three sides of the pad. Remove burrowing animals and repair damage.
- Control noxious and invasive weeds and shrubs and trees as they start to grow on the earth berm.
- Annually harvest filter strip vegetation to encourage dense growth and to maintain an upright growth habit. Controlled grazing may be used to remove the vegetation provided the animals are removed when stubble has been reduced to 3 to 4 inches tall. Controlled grazing should only be used when soil moisture conditions will support livestock traffic without excessive compaction.
- Remove manure to a field stacking site when full capacity is reached and more space is needed..
- Waste shall be removed from the stacking pad and utilized at locations, times, and rates in accordance with the Nutrient Management (590) developed for this farm
- Use caution when emptying the stacking pad so as not to damage the earth berm

EMERGENCY ACTION PLAN FOR MANURE SPILLS

Emergency Response Personnel

Name	Home Phone	Cell Phone	Pager

Recovery Equipment and Material

Equipment	Owner	Location	Phone
Sawdust bedding			
Hay bales			
Tractor, loader			
Backhoe			
Dozer			
Excavator			
Vacuum Type Septic Tank Pump Truck			

Preventing Spills:

- Don't fill the storage too full.
- Keep the area mowed around the storage to discourage woodchucks and other burrowing animals. Monitor for animal activity, patch holes, and remove animals.
- Make sure end gate is properly installed and tight before filling.
- Frequently monitor filling of storage, levels before and after rainfalls, and loads removed to better manage storage capacity and understand capacity changes with each inch of rainfall.
- Schedule routine maintenance of storage system. Keep written records of maintenance.
- Train employees to drive carefully. Transporting manure can be a source of spills. Tanker trailers, and manure spreaders can overturn, especially on narrow bridges and steep hills. Be careful when applying manure near open waterways.
- Identify all locations where system failure may occur, how serious a problem it may be, and ways to eliminate or stop the source of the spill or runoff.

Spills From Containment Breach or Structure Failure:

- Construct earthen dikes or use sawdust bedding or other materials to contain or divert spill away from watercourses, roadways, wells, lawns etc. Use sawdust bedding to soak up liquid manure where it can't be collected and pumped.
- Set up equipment and procedures to secure the structure from further release of manure. Utilize materials on the farm to contain the leak.
- Remove liquid spill from diked areas and low areas with vacuum type septic tank pump truck. Remove sawdust and manure with tractor loader. Transport to fields for spreading or to another storage.

Spills From Pumping Operation:

- Shut off pumping equipment.
- Use sawdust bedding or solid manure from pad to divert, or contain spill away from watercourses, roadways, and wells and lawns. Use sawdust bedding to soak up liquid manure.
- Remove liquid spill from diked areas and low areas with septic tank vacuum pump trucks. Remove sawdust and manure with tractor loader. Transport to fields for spreading or to another storage.

Spills During Transportation on Public Roadways:

- Coordinate efforts with local law enforcement and emergency personnel.
- Contain spill or divert manure away from watercourses, roadways or improved property.
- Remove solid manure with a tractor loader, backhoe, or excavator and transport to field for spreading.
- Wash liquid or slurry manure from roadways and public use areas into a contained area using a fire truck.
- Remove liquid spill from contained area with a vacuum type septic tank pump truck or front end loader if bedding was used to soak up the liquid.

Spill Reporting:

- Notify the local town emergency response personnel (Police or Fire Department) if manure spill threatens a water body.
- Information to provide when calling agencies include: name, telephone number, nature of emergency, location of spill including address and site description, direction of spill movement, the perceived impact, and any control action implemented.

Clean Up Spill Area:

- Remove dike and any materials used.
- Level any soil disturbance and incorporate any residue.

Documentation:

The following should be documented in writing and kept with the Emergency Action Plan for future reference and emergency response training:

- Date, time, location of spill, affected landowners
- Effect of manure spill on any surface water body or potable water well.
- Approximately how much manure was released and for what duration.
- Amount of manure, if any, that left the farm property.
- Any damage done, such as personal injury, fish kill, property damage.
- Cause of the spill.
- Procedure to handle the emergency.
- Clean up efforts.
- List of authorities called, those that responded, and the time it took for them to respond.
- Recommendations to prevent a reoccurrence.

ODOR CONTROL:

Barns should be routinely cleaned and bedding applied.

The stored manure, both liquid and solid, should not be disturbed until the time it is loaded for spreading.

Manure spread on land to be tilled should be incorporated as soon as possible to capture the ammonia-N.

Avoid spreading around holidays and on weekends when the weather is sunny and mild and neighbors are out and about.

Take the direction of the wind in consideration when spreading manure. Do not spread when the wind is blowing towards a neighbors home.

PEST CONTROL:

The stored manure, both liquid and solid, should not be disturbed until the time it is to be loaded for spreading.

A fly control program should be followed around the buildings and manure piles especially during warm weather.

Flies and other pests are to be controlled using materials and methods currently recommended by the Cooperative Extension Service.

Read the label before mixing and applying the spray materials. The label is the law.

The applicator must wear the protective equipment required by the label.

SECTION 4
LAND TREATMENT PRACTICES

Maps of Land Application Areas: *(may be located in Section 1)*

Identification of Sensitive Areas: *(may be located in Section 1)*

Soils Information: *(may to located in Section 1)*

RUSLE Calculations: *(as needed and could already be in the Conservation Plan)*

Crop Rotations Planned: *(as needed and could already be in the Conservation Plan)*

Proposed Locations of Planned Practices: *(show on field maps and describe)*

Operation and Maintenance for Practices Installed and Planned:

SECTION 5

SAMPLE FARM
NUTRIENT MANAGEMENT PLAN

OVERVIEW:

Nutrient Management is managing the source, rate, form, timing, placement and utilization of manure, other organic by-products, bio-solids, and other nutrients in the soil and residues. The goal is to effectively and efficiently use the nutrient resources to adequately supply soils for plants to produce food, forage, fiber, and cover while minimizing the transport of nutrients to ground and surface water and environmental degradation.

The potential environmental and health risks that can occur from excessive levels of nitrogen and phosphorus are the reasons for nutrient management. Nutrient Management plans are intended to prevent nutrients supplied for production purposes from contributing to water quality impairment. Nutrient Management plans also aim to adequately meet the crop nutrient requirements with nutrients produced on the farm to minimize the amounts of fertilizer that must be purchased.

GENERAL RECOMMENDATIONS:

The following are broad-based recommendations that should be considered when applying nutrients on crop, vegetable, or hay fields. They may not all be applicable for your operation as they are general recommendations for everyone.

- Timing of nutrient applications:
  - → Time applications to correspond as closely as possible with plant nutrient uptake, while considering cropping system limitations, weather and climatic conditions, and field accessibility. Consider splitting applications of nitrogen to provide it at the times of maximum crop needs.
  - → Time applications of animal manure to minimize odors to downwind neighbors. Do not spread when it is real windy or when you can not incorporate soon after spreading.
  - → Time applications to minimize potential runoff if rainfall is forecasted within 24 hours. Do not spread if you can not incorporate before rainfall occurs.
  - → If manure is to be spread on soils subject to flooding they should either be plowed down immediately or spread after the danger of flooding is minimal (about mid-June).
  - → Nutrients should not be applied to flooded or saturated soils when the potential for soil compaction and the creation of ruts is high.

- If spreading in the fall is necessary avoid sloping fields.

- Use of cover crops:
  - → Consider using cover crops whenever possible to tie up and recycle residual nitrogen in the soil. Cover crops also serve to trap phosphorus during periods of runoff.
  - → Fields with high intensity cropping cycles (for example corn or another tilled crop every year) should have a cover crop planted to take up some of the excess phosphorus in the soil.
  - → When spreading manure in the fall on tilled land, incorporate and plant a cover crop to reduce potential runoff and erosion.

- Erosion control and management of runoff water should be practiced to prevent pollution of surface waters.

- Do not spread directly in diversion channels, grassed waterways, or other areas of concentrated flow.

- Establish and maintain vegetated setbacks from environmentally sensitive areas such as sinkholes, wells, gullies, perennial streams, and waterbodies. The vegetation will act as a filter and prevent pollutants and excess nutrients from entering the sensitive area(s). Distances of 15 to 150 feet, depending on site conditions, can greatly improve water quality.

- If nitrogen needs to be conserved because allowable application rates are limited, spread only when it can be incorporated that day. This will reduce the amount lost to volatilization.

- Other nutrients besides nitrogen, phosphorus, and potassium are to be applied at rates consistent with soil test results and/or Cooperative Extension recommendations.

- Consider potential affects to National Register listed or eligible cultural resources and listed threatened or endangered species.

- A cropping sequence using a variety of crop types (grasses, legumes, summer annuals, winter annuals, or perennials) with various rooting characteristics (shallow roots, deep roots, fibrous root system, tap root) will better utilize the available nutrients in the soil over several years.

- Adjusting nutrient inputs based on the current levels of nutrients available and amount required for crop production is the best way to maintain crop production and avoid excess accumulations. Complete soil tests annually to measure the current levels of nutrients in the soil. Test manure and other organic material to obtain the nutrient content of that source. Add in any atmospheric deposition and nitrogen credits from previous legume crops to get the total nutrients available.

HOW PLAN WAS DEVELOPED:

The Nutrient Management Plan was developed according to the following 10 steps:

1) A farm resource inventory was conducted. *This involved—*
   a) Documenting the short and long term nutrient management goals
   b) Collecting field aerial photos, soils maps, and any other conservation plans (HEL plans for example)
   c) Organizing existing field information such as crop and manure history, soil tests, crop yield potentials, etc.
   d) Conducting a whole-farm field-by-field environmental assessment to locate environmentally sensitive features such as: proximity to wells and streams, shallow bedrock, leaching and runoff potential of soils, soil loss calculations, etc.
   e) Estimating the whole farm manure production and nutrient value if the farm has livestock
   f) Calculating an approximate whole-farm nutrient budget to estimate the balance between land base and manure produced

2) The overall cropping plan was established for the years that the nutrient management plan is intended to support the whole farm goals. This included the crops to be grown on each field, the planned rotation, tillage measures, realistic yield expectations, etc.
3) Manure was sampled and analyzed
4) Soil sampling was done and submitted for routine soil testing
5) A Phosphorus Risk assessment was completed for all fields to determine if the nutrient budget should be balanced for nitrogen or phosphorus.
6) Fields were evaluated by soil type to determine if there was a threat for nitrogen leaching. High-risk fields were noted for less nitrogen to be applied.
7) Fields were prioritized for manure and other nutrient application based on crop needs and environmental assessment results.
8) The manure application rate, or fertilizer rate, was then determined as well as the timing and method of application for each individual field using the recommendations from the soil test reports, the manure analysis, and the field resource inventory (including the P index and nitrogen leaching potentials).
9) Any additional fertilizer and/or aglime amounts were determined
10) Crop and nutrient spreading record keeping systems were established

Attached you will find your current nutrient management plan and the subsequent spreading recommendations that were developed using the previous ten steps. Please note the setbacks and other concerns per field. Also please remember that this is a plan that can change. It will have to be updated according to soil test results, new agricultural research, different Cooperative Extension recommendations, manure tests, different legume credits, different crop rotations, etc. It is also a plan that was developed according to the requirements of the current NRCS 590 standard and any applicable Federal, state, or local regulations or policies; and that changes in any of these requirements may necessitate a revision of the plan.

Table 1. Summary of Field Data.

Field names, Crops grown (corn, grass, barley pasture etc.), Planned Rotations, Acreage and Anticipated nutrient source and last soil test date:

Field Names	Crop(s) Grown and planned rotations C = corn, H = hay		Acres	Antic. Nut. Source	Last soil test date

SD = Solid Dairy manure
LD = Liquid Dairy manure
P = Poultry manure
U = Urea
SF = Starter Fertilizer
MP = Muriate of Potash

Manure Lab Test Results are attached for each manure type.

Whole Farm Nutrient Budget (attached) shows farm can utilize all nutrients produced. *(Use NH Manure Screening Tool Spreadsheet to document Nutrient Budget if land base is adequate)*

Manure is utilized as nutrients for the production of the farm's corn and hay crops. None is exported. Extra nutrients needed will be supplied by starter fertilizer for corn, urea and muriate of potash for topdressing of sod and side dressing of corn.

Nutrients to be imported: (where crop needs exceed nutrients produced)

__ commercial fertilizer
__ imported manure, specify type and amount____________________
__ non-regulated residuals (please list)_______________________
__ regulated residuals* (please list)________________________
__ Lower crop yields

* See DES Regulations for Sludge and Bio-solids

Nutrient Management Plans for Individual Fields
or Groups of Fields Having Similar Soil Test Values, Crop Management, and Soils

(Suggest using "Nut. Mgt Manual Calc worksheets" for displaying field data and application recommendations)

Field Information:

Field Name(s)	Acres	Soil Type and Slope	Resource Concerns

Spreading Setbacks from sensitive areas:

Crops Grown and Yield Goals:

Field(s)	Crops Grown	Rotations	Yield Goals

Limiting Nutrient

The limiting nutrient to balance on for manure application was determined using current soil test data and the N - Index and P - Risk Index. (*Suggest using P-Index Multi-field spreadsheet to document P Risk)*

Field(s)	Limiting Nutrient	Lbs. P_2O_5 for limiting manure application rate

Recommended Nutrient Applications to meet yield goal (lbs. per acre) from soil test.

Field(s)	Nitrogen	P_2O_5	K_20	Lime

Nutrient Balance Table

(may use NH Manure Screening Tool Spreadsheet to document Available and Needed Nutrients)

For Field(s):

Nutrient Sources **(Pounds per acre)**

CREDITS		**P_2O_5**	**K_2O**
1. N credits from previous legume crop		**N/A**	**N/A**
2. Residual N from previous manure		**N/A**	**N/A**
3. Other credits			
N credits-------------------------------------			
PLANT AVAILABLE NUTRIENTS			
4. Credits (from above)			
5. Starter fertilizer to be applied			
6. Planned manure application contribution			
7. Additional fertilizer needs:			
8. Total nutrient contributions (add 4,5,6,7)			
9. Nutrients Recommended (from Current Soils Tests)			
10. Lbs. P_2O_5 for limiting manure application rate if required to balance on P.			
11. Field balance (plus = excessive amounts minus = shortage)			

Method, Form and Planned Timing of Application:

OPERATION AND MAINTENANCE:

1) Calibrate application equipment to ensure uniform distribution of material at planned rates.
2) Maintain pH levels so that crops have the optimum ability to utilize the nutrients.
3) Conduct soil and manure tests according to the schedule established in your nutrient management plan.
4) Document the actual rate at which nutrients were applied in each field. When the actual rates used differ from the recommended and planned rates, records will indicate the reason for the differences.
5) Conduct a periodic plan review to determine if adjustments or modifications to the plan are needed. As a minimum, plans will be reviewed and revised with each soil test cycle. Plans should be reviewed and revised as necessary when changes occur with crop types, animal number changes, land base changes, etc. Document the dates of any plan reviews, the person performing the review, and recommendations that resulted from the review.
6) Maintain records to document plan implementation. Applicable records include:
   a) Soil test results and recommendations for nutrient application
   b) Quantities, analyses and sources of nutrients applied
   c) Dates and method of nutrient applications
   d) Crops planted, planting and harvest dates, yields, and crop residues removed
   e) Results of water, plant, and/or organic by-product analysis
7) Records should be maintained for at least five years; or for a period longer than five years if required by state, Federal, or local ordinances; or program or contract requirements.
8) Protect fertilizer and organic by-product storage facilities from weather and accidental spillage or leakage.
9) Workers should be protected from and avoid unnecessary contact with chemical fertilizers and organic by-products. Protection should include the use of protective clothing when working with plant nutrients. Extra caution must be taken when handling ammonia sources of nutrients, or when dealing with organic wastes stored in unventilated enclosures.
10) The disposal of material generated from cleaning nutrient application equipment should be spread on cropland according to label directions. Excess material should be collected and stored or field applied in an appropriate manner. Excess material should not be applied on areas of high potential risk for runoff and leaching.
11) The disposal or recycling of nutrient containers should be done according to state and local guidelines or regulations.

SECTION 6
RECORDKEEPING

End of year summary of manure and nutrient application and crop yield data

Table 2. Actual manure/crop history--field by field

Field/crop	Application dates/rates	Fertilizers/rates	Yields	Plant Date	Harvest Date	Notes

Notes: *Notes would include reasons for differences in actual vs. planned applications, weather factors, populations, problems etc.*

Emergency Spill Response Activities:

Date	Amount Spilled	Corrective Actions

Soil Tests Completed and Scheduled:

(Enclose a spreadsheet showing test schedule for each field)

Manure Analysis Results:

(File here or in Section 5)

Application Equipment Calibration:

Equipment Type	Date Completed	Comments

Record of Maintenance Activities:

Changes made to CNMP that were not revised into this plan:

SECTION 7
OTHER ACTIVITIES

Feed Management: (Discuss as necessary)

There is adequate land area to utilize the nutrients produced by the animal operation. Discussed Feed Management with landowner and he decided not to do anything with it at this time. Will evaluate this option in the future if nutrient overload becomes a problem.

Other Utilization Options: (Discuss as necessary)

SECTION 8
HELPFUL FACT SHEETS, ETC

Appendix A	Soil Testing Procedure
Appendix B	Manure Analysis Procedure
Appendix C	Application Equipment Calibration

Testing Your Soil

What is a Soil Test?

A routine soil test is a tool to manage the mineral nutrition of growing plants. It is a quick and inexpensive way to check the levels of essential soil nutrients. Soil is sampled and sent to a lab for analysis.

Why Test the Soil?

Homeowners, farmers and others often test soil from their gardens, yards and fields. The soil tests tell them soil pH and the level of nutrients that are available for plant growth.

The pH of the soil is a measurement of relative acidity. Soils that are too acid are not suitable for most plants.

The amount and balance of nutrients in the soil has an effect on plant growth, too. Low levels slow plant growth. High levels can pollute the environment or cause imbalances. A soil test lets you know if you need to add more nutrients and how much, if any, to add. It can save you money and prevent water pollution.

What Information Does a Soil Test Provide?

The soil test will tell you:

* the soil pH;
* levels of potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg);
* organic matter level;
* if there is lead contamination;
* how much lime and fertilizer (organic or chemical) to add; and
* other management tips for growing your crop.

How Often Should I Test the Soil?

Test your soil at least once every three years. Keep the test results handy so you can monitor any changes in soil fertility. You may want to test more often if you have a problem area or if you've applied lots of nutrients. Some people test their soil every year to save money on fertilizer, lime and other soil amendments. How often you test depends on the value of the crop and how closely you manage it.

What Time of Year Should I Test My Soil?

Recommendations are made for the next growing season, so you should test soil well before the growing season, such as early spring (after the frost is out of the soil) or in the fall before the ground freezes. A soil test usually takes two to three weeks (from shipping to the lab to return of results). Fall sampling will give the same results as spring sampling. With fall sampling, you will get results back in plenty of time for planting.

How Do I Take a Good Soil Sample?

1. Get a New Hampshire Soil Testing Information Sheet, bags, and tags Analytical Services Lab at the University of New Hampshire, Spaulding Life Science Center, Room G-54, Durham, NH 03824. Phone number 603-862-3210 and email Soil.Testing@unh.edu You can also go to the following web site to download the appropriate forms and cost data instead of sending for the testing information: http://aslan.unh.edu/UNHSoilTesting/Index.htm
2. Use a clean spade, trowel or soil probe to sample the soil. Take several *cores* (approximately 1 cup of material per core) in different spots to fully represent the garden or field. Collect one sample for each 20 acres (or 1 per field for small fields unless they contain similar soils and cropping patterns). For agricultural fields, take a minimum of one *core* per acre to make up the sample for the field. You will want to sample at rooting zone depth (usually six to eight inches for gardens or fields and three to four inches for sod or turf). Use a clean container to combine all of the *cores* to make up each sample. For agricultural fields, collect a subsurface sample made up of 6 to 8 *cores* per 20 acres at depths of 10 to 24 inches to test for nitrates in the subsurface zone which is still available for plant use.
3. Mix the soil thoroughly and fill the sample container with soil.
4. Label the container with your name, address and sample identification.
5. Fill out the information form as completely as possible.
6. Make a copy of the form for your records.
7. Put the sample container(s) and information (with check or money order) in a mailing container and mail to the address noted above.

How do I use the Soil Test Information?

Soil test analyses are reported as parts per million (ppm). The results are interpreted by test category and adjusted by soil: very low (VL), low (L), optimum (Opt), high (H), and very high (VH). The optimum category is the most profitable category to maintain over time. The low and very low categories indicate deficient soil test levels, while the high and very high categories indicate a higher test level than required for crop production.

Nutrient applications with soil test levels in the H and VH categories seldom generate a profitable yield response. The very high soil test category indicates that the nutrient concentration exceeds crop needs, and further additions of that nutrient very seldom produce a profitable yield response and may lead to environmental degradation or potential water quality problems in the area.

How to Sample Manure for Nutrient Analysis

Why Sample?

A field-by-field nutrient management program requires that multiple practices be implemented to maintain adequate fertility for crop growth and development. The program includes soil sampling for soil test analysis, crop rotation, and giving appropriate nutrient credit to legumes in the rotation. Manure sampling and manure spreader calibration are part of a comprehensive nutrient management program so manure can be credited effectively as a nutrient source. A well-designed soil sampling plan, along with manure sampling and nutrient analysis, can reduce input costs and the potential of environmental pollution.

One of the many factors affecting the nutrient content of manure is how the manure is handled and stored. Each handling system results in different types of nutrient losses - some unavoidable and others that can be controlled to a certain degree. The most important thing in collecting a manure sample is that it should be obtained in a similar way to the method used in developing standard nutrient value recommendations. The following guidelines are designed for collecting on-farm animal manure samples.

When do I Collect a Manure Sample?

Sample manure at the time of land application or as close as possible to application. Sampling at the time of land application will not provide manure nutrient recommendations that can be used at that time to adjust the amount of manure applied. The results, however, can be used for subsequent manure applications and to adjust commercial fertilizer application. Take manure samples every three to five years after establishing a base level or if animal management practices change significantly from present methods. If you apply manure several times a year, take samples when you plan to apply the bulk of manure. For example, sample in the spring when manure that has accumulated all winter will be used as a nutrient source.

Manure sampling should be done in the field as manure is land applied. This ensures that losses that occur during handling, storage, and application are taken into account.

How do I Collect a Manure Sample from the Field?

Manure accumulates in different types of livestock holding areas. These areas include barns and other similar housing - where manure is collected in gutters or in dry stacks - and open paved feedlots. It is recommended that manure from holding areas should be sampled during field application. Collect manure samples according to the following field sampling procedure.

1. Spread a sheet of plastic or tarp on the field. A 10 feet by 10 feet sheet works well for sampling manure.
2. Drive the tractor and manure spreader over the top of the plastic sheet to spread manure over the sheet.

3. Collect a manure sample using the hand-and-bag method described in the following section.

Dry or Solid Sample Preparations

The technique for collecting all solid manure samples is the hand-and-bag method. It is recommended a minimum of three subsamples be taken to obtain a representative sample of manure. When making nutrient recommendations, use an average of the three subsamples.

To collect samples, place a one-gallon resealable freezer bag turned inside out over one hand. Grab a handful of manure with the covered hand and turn the freezer bag right side out over the sample with the free hand. Seal the bag and place it in another freezer bag to prevent leaks. Label the bag for identification and **freeze** it immediately to prevent nutrient losses and minimize odors. Manure samples should be mailed or delivered to the laboratory as soon as possible.

Liquid Manure Sampling

Every effort should be made when sampling to agitate manure in the storage facility so a representative sample is obtained for laboratory analysis.

1. Immediately after filling the tank spreader, use a clean plastic pail to collect manure from the unloading port or the opening near the bottom of the tank. Be sure the port or opening does not have a solids accumulation.
2. Ensure that the manure in the pail is well-stirred and immediately fill a one-quart plastic sample bottle to within one inch from the top. Only one sample is necessary for liquid manure.
3. Be sure to put your name, date, and storage pit identification on the bottle.
4. If the sample cannot be transported to a laboratory within a few hours, it should be frozen. Place the container in a tightly sealed bag and keep cool until it can be taken to the laboratory.

Sampling from storage facilities directly is not recommended because of safety considerations and the difficulty of obtaining good representative samples. Manure stored outside in a solid waste storage facility or in a field stack is best sampled using the method described above for Dry or Solid Manure. Samples from the stack can be taken if collected from various locations within and along the sides for the stack, mixed and sampled using the hand-and-bag method described above. Three subsamples should be collected and averaged for the stack.

What will the Laboratory Analysis give me?

Manure samples should be sent to the lab for chemical analysis as quickly as possible to avoid nutrient losses. Basic manure analyses determined by the laboratory includes total Kjeldahl nitrogen (TKN), phosphate (P_2O_5), and potash (K_2O).

Results from commercial laboratories are presented as a percent of the sample weight, as pounds per ton or in pounds per 1,000 gallons of manure. In any case, manure values from commercial laboratories express nutrients as the total amount of nutrient available in the manure sample. Primary nutrients (N, P, and K) are not all available for plant growth the first year manure is applied. A portion of some nutrients is present in manure in an organic form and unavailable for plant uptake. Organic nutrients require transformation to an inorganic state to be available for plant uptake.

This transformation is dependent on temperature, moisture, chemical environment, and time. Availability of nutrients can be limited by field losses, which are affected by types of manure and by manure application methods. These losses are not accounted for in laboratory results. Refer to the NRCS Practice Standard 590 - Nutrient Management for information on availability based on application and incorporation data.

In New Hampshire, manure samples need to be sent to the following address for analysis: University of Vermont, Agricultural and Environmental Testing Lab, 219 Hills Building, Burlington, VT 05405-0082. Phone number is 802-656-3030.

Application Equipment Calibration:

Commercial Fertilizer Application Equipment Calibration:

The nitrogen applicator, the commercial broadcast spreaders, and corn planter will be set per the manufacturers recommendations then filled with an known amount and checked over known acreage. Adjustments will be made to achieve the planned rates.

Manure Spreader Calibration

There are several methods that can be used to calibrate the application rate of a manure spreader. The two best methods are the load-area method and the plastic sheet method. It is desirable to repeat the calibration procedure 2 to 3 times and average the results to establish a more accurate calibration.

Before calibrating a manure spreader, the spreader settings such as splash plates should be adjusted so that the spread is uniform. Most spreaders tend to deposit more manure near the spreader than at the edge of the spread pattern. Overlapping can make the overall application more uniform. Calibrating of application rates when overlapping requires measuring the width of two spreads and dividing by two to get the effective spread width.

Calibration should take place annually or whenever manure is being applied from a different source or consistency.

Load-Area Method

The load-area method is the most accurate and can be used for most types of manure handling. This method consists of determining the amount (volume or weight) of manure in a spreader and the total area over which it is applied. The most accurate method to determine the amount of manure in a spreader is to weigh the spreader when it is full of manure and again when it is empty (portable pad scales work well for this). The difference is the quantity of manure applied over the area covered. Spreader capacities listed by the manufacturers can be used to determine the amount of manure in the spreader. However care must be taken when using manufactures spreader capacities. Heaped loads, loading methods and manure type may vary considerably from what is listed by manufacturers of box and side delivery manure spreaders. Spreader capacities for liquid tankers are accurate provided the tanker is filled to the manufactures recommended levels, and no foam is present in the tank.

The area of spread is determined from measuring the length and width of the spread pattern. Measuring can be done with a measuring wheel, measuring tape or by pacing.

The application rate is calculated by dividing the amount of manure in the spreader (Tons or gallons) by the area it is spread over (square feet) times 43,560 sq. ft./acre.

Formula:

$$\frac{\text{Spreader capacity (tons or gallons)}}{\text{Distance traveled X Spreading width}} \text{ X } 43560 \text{ sq. ft/acre} = \text{Application Rate tons or Gallons/Acre}$$

Plastic Sheet Method

The plastic sheet method can only be used with solid or semi-solid manure. This method of calibrating spreader application rates involves **1)** cutting a plastic sheet to the specified dimensions (56 inches X 56 inches), **2)** weighing the clean plastic sheet, **3)** laying out the plastic sheet on the ground and driving the manure spreader (applying manure at a recorded speed and spreader setting) over the sheet, **4)** weighing the plastic sheet with the manure on it, and **4)** determine the net weight of the manure on the sheet (weight of manure and sheet - weight of the clean sheet), and **5)** the net pounds of manure equals tons per acre applied.

When calibrating manure spreaders, all details regarding tractor speed and manure spreader settings and date(s) of each calibration should be recorded with manure application information, and directly on the equipment. Mark equipment to ensure a known application rate is applied each time the referenced tractor speed and spreader settings are used. Manure spreader settings can include such things as: fast and slow settings on some box spreaders, gate position on side delivery spreaders and splash plate position and fill levels on liquid tankers.

Part 600.5 – Comprehensive Nutrient Management Planning Technical Guidance

Subpart E

Part 600.5 – Comprehensive Nutrient Management Planning Technical Guidance

600.50 - Background

Conservation planning is a natural resource problem-solving process. The process integrates ecological (natural resource), economic, and production considerations in meeting both the owner's/operator's objectives and the public's natural resource protection needs. This approach emphasizes identifying desired future conditions, improving natural resource management, minimizing conflict, and addressing problems and opportunities. Comprehensive nutrient management plans (CNMPs) are developed in accordance with NRCS conservation planning policy and rely on the planning process and established conservation practice standards.

A CNMP identifies management and conservation actions that will be followed to meet clearly defined soil and water conservation goals, including nutrient management, on an animal feeding operation (AFO). Defining soil and water conservation goals and identifying measures and schedules for attaining these goals are critical to reducing potential and actual threats to water quality and public health from AFOs. The CNMP fits within the total resource management objectives of the entire farm/animal feeding operation.

The CNMP Technical Guidance is for use by those individuals who develop or assist in the development of CNMPs. The purpose of this document is to provide technical guidance for the development of CNMPs, whether they are developed for USDA ' s voluntary programs or as a means to help satisfy the United States Environmental Protection Agency's (USEPA) National Pollutant Discharge Elimination System (NPDES) permit requirements.

The Technical Guidance is not intended as a sole-source reference for developing CNMPs. Rather, it is to be used as a tool in support of the NRCS conservation planning process, as described in the preceding Sections 600 through 600.4 of this handbook and NRCS Technical References, Handbooks, and Policy Directives. The conservation planning process has not been changed by the introduction of CNMPs.

600.51 - Definition of a Comprehensive Nutrient Management Plan (CNMP)

A CNMP is a conservation plan that is unique to animal feeding operations. It is a grouping of conservation practices and management activities which, when implemented as part of a conservation system, will help to ensure that both production and natural resource protection goals are achieved. A CNMP incorporates practices to utilize animal manure and organic by-products as a beneficial resource. A CNMP addresses natural resource concerns dealing with soil erosion, manure, and organic by-products and their potential impacts on water quality, which may derive from an AFO. A CNMP is developed to assist an AFO owner/operator in meeting all applicable local, tribal, State, and Federal water quality goals or regulations. For nutrient impaired stream segments or water bodies, additional management activities or conservation practices may be required to meet local, tribal, State, or Federal water quality goals or regulations.

The conservation practices and management activities planned and implemented as part of a CNMP must meet NRCS technical standards. For those elements included by an owner and/or operator in a CNMP for which NRCS currently does not maintain technical standards (i.e., feed management, vector control, air quality), producers should meet criteria established by Land Grant Universities, industry, or other technically qualified entities. Within each state, the NRCS State Conservationist has the authority to approve non-NRCS criteria established for use in the planning and implementation of CNMP elements.

600.52 - Objective of a CNMP

The objective of a CNMP is to document the AFO owner's and/or operator's plan to manage manure and organic by-products by combining conservation practices and management activities into a conservation system that, when implemented, will achieve the goal of the producer and protect or improve water quality.

In developing a CNMP with an AFO owner and/or operator, alternatives are developed that address treatment of the resources of concern and are in accordance with the applicable NRCS technical standards. The AFO owner/operator, as decision-maker, selects from these alternatives to create a CNMP that best meets his/her management objectives and environmental concerns.

CNMP implementation may require additional design, analysis or evaluations. It is important for the certified conservation planner to maintain a relationship with the producer throughout CNMP implementation to address changes or new challenges. Evaluation of the effectiveness of the CNMP may begin during the implementation phase and not end until several years after the last practice is applied. Follow-up and evaluation determines whether the implemented alternative is meeting the client needs and solving the conservation problems in a manner beneficial to the resources.

600.53 - General Criteria for CNMP Development

CNMPs will, as a minimum, meet the following criteria:

- Provide documentation that addresses the items outlined in Section 600.6, Exhibit 15, Comprehensive Nutrient Management Plan-Format and Content.
- Document the AFO owner's/operator's consideration of the six CNMP elements. It is recognized that a CNMP may not contain all six elements; however, they need to be considered by the AFO owner/operator during development of the CNMP, and the owner's and/or operator's decisions regarding each must be documented. These elements are as follows:
  - Manure and Wastewater Handling and Storage
  - Land Treatment Practices
  - Nutrient Management
  - Record Keeping
  - Feed Management
  - Other Utilization Activities
- CNMPs will contain actions that address water quality criteria for the feedlot, production area, and land on which the manure and organic by-products will be applied (i.e., as a minimum the plan would address CNMP element numbers 1, 2,3, and 4 listed above). This includes addressing soil erosion to reduce the transport of nutrients within or off of a field to which manure is applied. For AFO owners and/or operators who do not land apply any manure or organic by-products, the CNMP would address only the feedlot and production areas (i.e., address CNMP element numbers 1,4, and 6 listed above).
- Meet requirements of the NRCS Field Office Technical Guide (FOTG) conservation practice standards for all practices contained in the CNMP.
- Meet all applicable local, Tribal, State, and Federal regulations. When applicable, ensure that USEPA-NPDES or State permit requirements (i.e., minimum standards and special conditions) are addressed.

600.54 - Element Criteria for CNMP Development

The degree to which each CNMP element is addressed is determined by the General Criteria (NPPH, Section 600.53) and the specific criteria provided for each element in this section.

(a) Manure and Wastewater Handling and Storage

This element addresses the components and activities associated with the production facility, feedlot, manure and wastewater storage and treatment structures and areas, and any areas used to facilitate transfer of manure and wastewater. In most situations, addressing this element will require a combination of conservation practices and management activities.

(1) Criteria for Manure and Wastewater Handling and Storage

Provide for adequate collection, storage, and/or treatment of manure and organic by-products that allows land application in accordance with NRCS Nutrient Management Policy and the conservation practice standard for Nutrient Management (Code 590). Collection, storage, treatment, and/or transfer practices shall meet the minimum requirements as addressed in the following NRCS conservation practice standards contained in Section IV of the NRCS FOTG, as appropriate:

- Waste Storage Facility (Code 313)
- Waste Treatment Lagoon (Code 359)
- Manure Transfer (Code 634)
- Heavy Use Protection Area (Code 561)

Comply with existing federal, Tribal, State, and local regulations, associated with the following activities:

- Disposal of dead animals.
- Disposal of animal medical wastes.
- Disposal of spoiled feed or other contaminants that may be regulated by other than an NPDES or State concentrated animal feeding operation (CAFO) permitting program.

Note: NRCS does not have national conservation practice standards that address all these activities. Generally, federal, Tribal, State and local regulations dictate acceptable procedures, however, NRCS in some States has developed standards that address the disposal of dead animals by incineration or freezing.

Document the following:

- Types of animals and phases of production that exist at the facility.
- Numbers of each animal type, average weight, and period of confinement for each phase of production.
- Total estimated manure and wastewater volumes produced at facility. Where historical manure and wastewater production volumes are not documented, an estimate may be made using the procedures and tabular data provided in the NRCS Agricultural Waste Management Field Handbook (AWMFH), Chapter 4, "Waste Characteristics".
- Manure storage type, volume, and length of storage. (For more information on storage and treatment systems, how they function, their limitations, and design guidance see NRCS AWMFH, Chapter 9, "Animal Waste Management Systems", and Chapter 10, "Component Design").
- Existing transfer equipment, system, and procedures.

- Operation and maintenance activities that address the collection, storage, treatment, and transfer of manure and wastewater, including associated equipment, facilities, and structures.
- Nutrient content and volume of manure, if transferred to others.
- An emergency action plan to address spills and catastrophic events.

(2) Considerations for Manure and Wastewater Handling and Storage

Additional considerations associated with CNMP development and implementation should be addressed. However, NRCS does not have specific technical criteria for these considerations required for CNMPs. These considerations are:

(i) Air Quality

During the CNMP development process, APO operators and/or owners need to consider the impact of selected conservation practices on air quality. Air quality in and around structures, waste storage areas, and treatment sites may be impaired by excessive dust, gaseous emissions, and odors. Poor air quality may affect the health of workers, animals, and persons living in the surrounding areas. Ammonia emissions from animal operations may be deposited to surface waters, increasing the nutrient load. Proper siting of structures and waste storage facilities can enhance dispersion and dilution of odorous gases. Conservation buffers placed with regard to prevailing wind patterns can intercept movement of some airborne pollutants. Enclosing waste storage or treatment facility can reduce gaseous emissions from AFOs in areas with residential development.

(ii) Pathogens

During the CNMP development process, AFO operators and/or owners need to consider the impact of selected conservation practices on pathogen control. Pathogenic organisms occur naturally in animal wastes. Exposure to some pathogens can cause illness to humans and animals, especially for immune-deficient populations. Many of the same conservation practices used to prevent nutrient movement from animal operations, such as leaching, runoff, and erosion control are likely to minimize the movement of pathogens. Certain waste treatment systems can further reduce the pathogen content of manure.

(b) Land Treatment Practices

This element addresses evaluation and implementation of appropriate conservation practices on sites proposed for land application of manure and organic by-products from an AFO. On fields where manure and organic by-products are applied as beneficial nutrients, it is essential that runoff and soil erosion be minimized to allow for plant uptake of these nutrients. An understanding of the present land use of these fields is essential in developing a conservation system to address runoff and soil erosion adequately.

(1) Criteria for Land Treatment Practices

- An on-site visit is required to identify existing and potential natural resource concerns, problems, and opportunities for the conservation management unit (CMU).
- Identification of the potential for nitrogen and phosphorus losses from the site.
- At a minimum, the conservation system developed for this element will address the NRCS Quality Criteria for water quality, found in Section III of the FOTG. Soil erosion is to be addressed to reduce the transport of manure nutrients within or off of a field to which manure is applied. Typical NRCS conservation practices, and their

corresponding NRCS conservation practice standard code number, used as part of a conservation system to minimize runoff and soil erosion are:
    - Conservation Crop Rotation (Code 328)
    - Residue Management, No Till and Strip Till (Code 329A)
    - Residue Management, Mulch Till (Code 329B)
    - Residue Management, Ridge Till (Code 329C)
    - Contour Buffer Strips (Code 332)
    - Cover Crop (Code 340)
    - Residue Management, Seasonal (Code 344)
    - Diversion (Code 362)
    - Windbreak and/or Shelterbelt Establishment (Code 380)
    - Riparian Forest Buffer (Code 390)
    - Filter Strip (Code 393)
    - Grassed Waterway (Code 412)
    - Prescribed Grazing (Code 528A)
    - Stripcropping (Code 585)
    - Terrace (Code 600)
- Compliance with existing, federal, Tribal, State and Local regulations or ordinances associated with soil erosion and runoff.
- Document the following:
    - Land application areas on aerial photos.
    - Individual field maps with setbacks, buffers, waterways, and other planned conservation practices marked.
    - Soils information such as features, limitations, and capability for each field.
    - Conservation practice design information.
    - Identification of sensitive areas such as sinkholes, streams, springs, lakes, ponds, wells, gullies, and drinking water sources.
- Other site information features of significance, such as property boundaries.
- Identification of operation and maintenance (O&M) practices and/or activities.

(c) Nutrient Management

This element addresses the requirements for land application of all nutrients and organic by-products that must be evaluated and documented for each CMU.

Land application of manure and organic by-products is the most common use of manure because of the nutrient and organic matter content of the material. Land application procedures must be planned and implemented in a way that minimizes potential adverse impacts to the environment and public health.

(i) Criteria for Nutrient Management

- Meet the NRCS Nutrient Management Policy as contained in the General Manual, Title 190, Part 402, (May 1999), and clarified by the National Instruction, Nutrient Management -Policy Implementation, Title 190, Part 302, October 2000.
- Meet criteria in NRCS conservation practice standard Nutrient Management (Code 590) and, as appropriate, Irrigation Water Management (Code 449).
- Develop a nutrient budget for nitrogen, phosphorus, and potassium that includes all potential sources of nutrients.
- Document the following:
    - Planned crop types, cropping sequence, and realistic yield targets.

- Current soil test results for nitrogen, phosphorus, potassium, heavy metals, and sodic condition.
- Manure and organic by-product source testing results.
- Form, source, amount, timing, and method of application of nutrients, by field.
- Description of application equipment and method used for calibration.

(ii) Considerations for Nutrient Management

Additional considerations associated with CNMP development and implementation should be addressed. However, NRCS does not have specific required technical criteria for these considerations for CNMPs. These considerations are:

Air Quality

AFO operators/owners should consider the impact of selected conservation practices on air quality during the CNMP development process. Air quality on land application sites may be impaired by excessive dust, gaseous emissions, and odors. Poor air quality may affect the health of workers, as well as animals and persons living in the surrounding areas. Ammonia emissions from animal operations may be deposited to surface waters, increasing the nutrient load. Soil incorporation of manure and organic by-products on land application sites can reduce gaseous emissions.

Pathogens

AFO operators and/or owners should consider the impact of selected conservation practices on pathogen control during the CNMP development process. Pathogenic organisims occur naturally in animal waste. Exposure to some pathogens can cause illness in humans and animals, especially for immune-deficient populations. Many of the same conservation practices used to prevent nutrient movement from animal operations, such as leaching, runoff and erosion control, are likely to prevent the movement of pathogens.

Salt and Heavy Metals

Build up of salt and heavy metals (i.e., arsenic, selenium, cadmium, molybdenum, zinc) in soils can create a potential for human and animal health problems and threaten soil productivity and crop marketability. Federal and State regulations do not address the heavy metal content associated with agricultural by-products. In developing a CNMP, the build-up of salt and heavy metals should be tracked through soil testing. Additional guidance on salt and heavy metal contamination from manure is available in the following:

- NRCS Agricultural Waste Management Field Handbook, Sections 651.1103 and 651.0604(b) deal with the salt content of agricultural waste.
- NRCS Agricultural Waste Management Field Handbook, Sections 651.0603(g) and 651.0605(a and b) deal with the heavy metal content of agricultural waste.
- USEPA Title 40 Part 503 -Standards for the Use or Disposal of Sewage Sludge. Section 503.13 contains pollutant limits for biosolids heavy metal content and cumulative loading rates, but does not address resident levels of metals in the soil.

(d) Record Keeping

It is important for AFO owners and/or operators to document and demonstrate implementation activities associated with their CNMPs. Documentation of implementation and management activities associated with a CNMP provides valuable benchmark information that the AFO owner/operator can use to adjust his/her CNMP to meet production and natural resource conservation objectives.

It is the responsibility of AFO owners and/or operators to maintain records that document the implementation and management of CNMPs.

Documentation will include:

- Annual manure tests for nutrient contents for each manure storage containment.
- Current soil test results, in accordance with Nutrient Management Code 590.
- Application records for each manure or commercial fertilizer application event, including:
    - Containment source or type and form of commercial fertilizer,
    - Field(s) where manure or organic by-products are applied,
    - Amount applied per acre,
    - Time and date of application,
    - Weather conditions during nutrient application,
    - General soil moisture condition at time of application (i.e., saturated, wet, moist, dry), and
    - Application method and equipment used.
- Crops planted and planting and/or harvesting dates, by field.
- Records that address manure and wastewater storage containment structures:
    - Dates of emptying, level before emptying, and level after emptying,
    - Discharge or overflow events, including level before and after event.
- Transfer of manure off-site or to third parties:
    - Manure nutrient content,
    - Amount of manure transferred,
    - Date of transfer, and
    - Recipient of manure.
- Activities associated with emergency spill response plan.
- Records associated with any reviews by NRCS, third-party consultants, or representatives of regulatory agencies:
    - Dates of review,
    - Name of reviewer and purpose of the review,
    - Recommendations or follow-up requirements resulting from the review, and
    - Actions taken as a result of the review.
- Records of maintenance performed associated with operation and maintenance plans.
- Nutrient application equipment calibration.
- Changes made in CNMP.

(e) Feed Management

Feed management activities may be used to reduce the nutrient content of manure that may result in less land being required to effectively utilize the manure. Feed management activities may be dealt with as a planning consideration and not as a requirement that addresses specific criteria; however, AFO owners and/or operators are encouraged to incorporate feed management as part of their nutrient management strategy. Specific information and recommendations should be obtained from the Cooperative State Research, Education, and Extension Service; Land Grant Universities; industry; the Agricultural Research Service; or professional societies such as the Federation of Animal Science Societies (FASS) or American Registry of Professional Animal Scientists (ARPAS); or other technically qualified entities.

An example of the effective use of feed management is presented as follows:

"If a dairy cow is fed 0.04 percent above recommended levels of dietary phosphorus she will excrete an additional six pounds of phosphorus annually. For a herd of 500 cows, this is an additional 3,000 pounds of phosphorus per year. In a single cropping system, corn silage is about 0.2 percent phosphorus on a dry matter basis. For a field yielding 30 tons of silage per acre, at 30 percent dry matter, this is 36 pounds of phosphorus in the crop. If an additional 3,000 pounds of phosphorus are recovered in manure it takes considerably more land for application if manure is applied on a phosphorus basis" Dr. Deanne Meyer, Livestock Waste Management Specialist, Cooperative Extension, University of California.

Specific feed management activities to address nutrient reduction in manure may include phase feeding, amino acid supplemented low crude protein diets, or the use of low phytin phosphorus grain and enzymes, such as phytase or other additives.

Feed management can be an effective approach to addressing excess nutrient production and should be encouraged; however, it also is recognized that feed management may not be a viable or acceptable alternative for all AFOs. A professional animal nutritionist should be consulted before making any recommendations associated with feed ration adjustment.

(f) Other Utilization Activities

Using environmentally safe alternatives to land application of manure and organic by-products could be an integral part of the overall CNMP. Alternative uses for animal manure are needed in areas where nutrient supply exceeds the nutrient requirements of crops, and/or where land application would cause significant environmental risk. Manure use for energy production, including burning, methane generation, and conversion to other fuels, is being investigated and even commercially tested as a viable source of energy. Methods to reduce the weight, volume, or form of manure, such as composting or pelletizing, can reduce transportation cost, and create a more valuable product. Manure can be mixed or co-composted with industrial or municipal by-products to produce value-added material for specialized uses. Transportation options are needed to move manure from areas of over supply to areas with nutrient deficiencies (i.e., manure brokering).

More efficient and cost-effective methods are needed for manure handling, treatment, and storage. Areas in need of targeting include:

- Improved systems for solids removal from liquid manure.
- Improved manure handling, storage, and treatment methods to reduce ammonia volatilization.
- Treatment systems that transform and/or capture nutrients, trace elements, and pharmaceutically active compounds from manure.
- Improved composting and other manure stabilization techniques.
- Treatment systems to remediate or replace anaerobic lagoons.

As many of these alternatives to conventional manure management activities have not been fully developed or refined, industry standards do not always exist that provide for their consistent implementation. NRCS does not have conservation practice standards that address these other utilization options.

This element of a CNMP should be presented as a consideration for the AFO owner and/or operator in his/her decision-making process. No specific criteria need to be addressed unless an alternative utilization option is decided upon by the AFO owner and/or operator. When an AFO owner and/or operator implements this element, applicable industry standards and all federal, Tribal, State, and local regulations must be met.

Exhibit 15 - Comprehensive Nutrient Management Plan - Format and Content

A comprehensive nutrient management plan (CNMP) should address all land units that the animal feeding operation (AFO) owner and/or operator owns or has decision-making authority over **and** on which manure and organic by-products will be generated, handled, stored, or applied. This Exhibit describes the general contents of a CNMP and lists suggested items under each major section. The intent of this guidance is to help to maintain quality and provide appropriate documentation of a CNMP. The precise content of a CNMP will vary as it is tailored to the meet the needs of the AFO owner and/or operator.

Contents of a Comprehensive Nutrient Management Plan

1. Site information

- Names, phone numbers, and addresses of the AFO owner(s) and operator(s).
- Location of production site: legal description, driving instructions from nearest post office, and the emergency 911 coordinates.
- Farmstead sketch.
- Plat map or local proximity map (Optional).
- Emergency action plan covering: fire, personal injury, manure storage and handling, and land application operations.
- Operation procedures specific to the production site and practices.
- Existing documentation of present facility components that would aid in evaluating existing conditions, capacities, etc. (i.e., as-built plans, year installed, number of animals a component was originally designed for, etc.).

2. Production information

- Animal types, phases of production, and length of confinement for each type at this site.
- Animal count and average weight for each phase of production on this site.
- Calculated manure and wastewater volumes for this site.
- Manure storage type, volume, and approximate length of storage.

3. Applicable permits or certifications

- Federal, Tribal, State or local permits and/or ordinances.
- Operator or manager certifications.
- Manure applicator certifications.
- Record of inspections or site assessments.
- Changes made to CNMP.

4. Land application site information

- Date plan prepared.
- Written manure application agreements. (Where Applicable)
- Aerial maps of land application area.
- Individual field maps with marked setbacks, buffers, and waterways, and environmentally sensitive areas, such as sinkholes, wells, gullies, tile inlets, etc.
- Landowner names, addresses, and phone numbers.
- Legal description of land sites, including watershed codes.
- Specific and unique field identification codes.
- Land use designation.

- Soil map, with appropriate interpretations.
- Risk assessments for potential nitrogen or phosphorus transport from fields. (See NRCS GM_190, Part 402, Nutrient Management, Section 402.07)
- Land treatment practices planned and applied, and level of treatment they provide.

5. Manure application plans

- Crop types, realistic yield targets, and expected nutrient uptake amounts.
- Application equipment descriptions and methods of application.
- Expected application seasons and estimated days of application per season.
- Estimated application amounts per acre (volume in gallons or tons per acre, and pounds of plant available nitrogen, phosphorous as P205, and potassium as K20 per acre).
- Estimate of acres needed to apply manure generated on this site, respecting any guidelines published for nitrogen or phosphorous soil loading limits.

6. Actual activity records

- Soil tests not more than 5 years old.
- Manure test annually for each individual manure storage containment.
- Planned and applied rates, methods of application, and timing (month and year) of nutrients applied. (Include all sources of nutrients, i.e., manure, commercial fertilizers, etc.)
- Current and planned crop rotation.
- Weather conditions during nutrient application. (Optional)
- General soil moisture condition at time of application (i.e., saturated, wet, moist, dry). (Optional)
- Actual crop and yield harvest from manure application sites.
- Record of internal inspections for manure system components.
- Record of any spill events.

7. Mortality disposal

- Plan for mortality disposal.
- Methods and equipment used to implement the disposal plan.

8. Operation and Maintenance

- Detailed operation and maintenance procedures for the conservation systems, holding facility, etc., contained in the CNMP. This would include procedures as calibration of land application equipment, storage facility emptying schedule, soil and manure sampling techniques, etc.

Conclusions

Development of a swine comprehensive nutrient management plan includes many different items. Plans should be developed including the following items:

- Animal numbers for each animal group
- The average weight of each of these animal groups
- Manure production
- Dilutions (Washwater and Rainfall) additions to the manure
- The manure storage facility and associated management problems
- Required best management practices around the barnyard and the manure storage
- Field evaluations of the areas that will be receiving manure applications

The last item that should be included in a CNMP is a list of the records that are needed to implement the plan. The operator should be informed of the records that he needs to maintain. A system should be developed so that they can easily implement the plan and collect the required data. A CNMP should be a continuing evolving plan that needs to be evaluated annually, incorporating the records that have been collected.

Nutrient Management Plans — Dairy

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Biographies for most speakers are in alphabetical order after the last paper.

Introduction

One of the biggest challenges in the dairy industry is complying with current environmental standards. Developing a comprehensive nutrient management plan (CNMP) to meet these demands involves the whole farm operation. The CNMP planner needs to become part of the dairy operation team in order to address all the farm's environmental concerns while keeping a strong focus on its economic viability.

Developing a CNMP plan takes time and implementing the plan can be costly. The cooperation of many individuals, though time consuming, is essential to the successful creation and implementation of the farm plan. For example, a farmer, working with the farm's experts, will focus on developing a business plan while the nutritionist prescribes ways to increase forage consumption and limit the amount of imported nutrients, especially phosphorus. A Certified Crop Advisor (CCA) will utilize the field nutrients indicated on soil tests and prescribe cost effective and environmentally responsible rates of nutrients to be applied through farm waste and chemical fertilizers. NRCS and Soil and Water District personnel will design conservation plans that keep soil loss to a minimum and the certified engineer will design structures that can contain the waste during a 25 year storm event. The goal of the planner, working with these outside experts and farm employees, is to help the grower design a business strategy that addresses water quality issues and improves the farm's profitability.

Main Components in the Plan

In designing a Dairy CNMP there are three main components:

- Farmstead Plan
- Waste Utilization Plan
- Records

Farmstead Plan

The farmstead component is divided into four sections. The information the planner gains from the first three; the executive summary, a five year business plan, and evaluation of the farmstead's present environmental conditions, is used to develop the final section, a plan to bring the farm into compliance with the current standards. There is no one-size-fits- all method for reaching farm compliance. Every aspect of each farm must be considered individually.

The first section of a CNMP is the the executive summary describing the farm setting, soils, total animal units, herd average, crop acres, and the average production for each commodity grown over the past three years. It also identifies water sheds and the sensitivity concerns for each water body.

The water shed drives the whole plan. The distance from the local water body and the sensitivity within that water body need to be considered. Information concerning the watershed priority nutrient(s) of concern may be obtained from the county water quality committee and may include sediments, biochemical oxygen demand (BOD), specific nutrients such as nitrogen or phosphorus, and pathogens. As well as addressing watershed concerns, the planner determines realistic nutrient application rates based on the past three years' average crop yields and assesses the concentration of animal units based on available acreage.

The second component, the business plan, defines the goals and objectives for the farm over the next five years. It helps the owner to formulate a course of action and develop budgets. If the farmer intends to expand, then a plan is needed to define where the new barn site will be and limit the possibility of adversely affecting the environment. It is also necessary to determine if there is a large enough land base for spreading manure or if solutions for exporting the excess nutrients must be considered.

The third component, determining environmental compliance, includes assessing the farmstead's ability to withstand a 25 year/24 hour storm event. This is more challenging for dairy operations than with other livestock. Wastes from barnyards, forage bunks, and parlors need to be either collected or treated using a proper filter system. Clean water should be diverted from barnyards and bunks through gutters, tile lines, or gravel drip trenches in order to keep it clean.

A barnyard is designated as any open area for cattle where there is no supporting vegetated areas to feed upon. An overgrazed pasture with limited vegetation can be classified as a barnyard area. With these exercise lots, the bottom line is, during a heavy rain event, is there enough area to filter the contaminated water before it enters a water body? Possible solutions for problem areas include reducing the size of the barnyard area and increasing the filter field, moving the exercise lot to another location to provide enough grass filter strips

between the lot and the water course, or increasing the pasture size to reduce over grazing. The planner will work with the farmer to find the solution that best fits the operation.

Leachate from the bunk typically is treated using two systems. One is a low flow collection that gathers high concentrate silage juices and diverts them to a underground tank or sends them to the manure storage. The other system is the high flow system which takes over during times of heavy precipitation. A percentage of the leachate that is diluted with the clean water will continue over the low flow collection to the filter system. This system must be able to handle a 25 year/ 24 hour storm event.

A problem peculiar to dairy operations is dealing with parlor waste. The BOD from the milk house is too high to be stored in a leachate field. The most practical way to store parlor waste is in a manure storage, although another possible solution is to filter it through a grass strip.

After evaluating the farmstead, the planner will make recommendations to bring the farm up to compliance. These will also take into consideration future plans outlined by the farm operator. At this point in the process, an engineer may be employed to design any necessary systems.

WASTE UTILIZATION PLAN

The purpose of the waste utilization plan is to measure whether or not the farm has a large enough land base to accommodate the waste produced, determine if storage needs to be constructed or expanded, and designate the proper time to spread manure. This is determined based on two major aspects :

1. Accounting for the total amount of nutrients to be spread or exported:
   - Manure produced
   - Uncollected Manure - Days in pasture
   - Types of Manure - Liquid, semi solid, solid
   - Bedding types and amounts
   - Milk house waste if collected
   - Other liquids, including rainfall
   - Manure sample

2. Define the Farm Land Base
   - Design farm field maps with acres and field ID
   - Crop rotations designating highly erodible fields
   - Soil names with drainage
   - Soil test crop fields (all fields sampled within the past 3 yrs)
   - Hydrologicly sensitive areas (HSA)
   - Slope length and gradient
   - Flooding Frequency
   - Winter Access
   - Neighbor relations

The first step in the plan is to determine the total manure produced from each storage system. The total amount of manure produced should be estimated based on the milk production of cows and the weight of calves and heifers (see Table 1). Bedding will add to manure and must be calculated into the equation. If it is a liquid system, sawdust is approximately 85 percent void while sand is 35 percent void, therefore a straight addition calculation is ineffective. Annual precipitation and evaporation must be considered as well when dealing with an outside manure storage. Other liquids from barnyard runoff and silage leachate should be estimated and calculated into the total waste.

The formula for calculating the total waste to be spread is:

Total Waste = Manure Produced + Bedding + Parlor Waste + Other liquids (silage Leacate, rainfall, etc.) - Uncollected Manure (days in pasture or barnyard)

Table 1. Manure Production Per Cow Based on Milk Production

Milk Production Rate Lbs cow /Day Lbs cow/Yr	Manure Gal/Day	Manure Gal/Yr	Manure Tons/Yr
50 lbs/Day 15250 lbs/Yr	15.1	5,511	22
55 lbs/Day 16775 lbs/Yr	16.2	5,913	23.6
60 lbs/Day 18300 lbs/Yr	17.2	6,278	25.1
65 lbs/Day 19825 lbs/Yr	18.3	6,679	26.7
70 lbs/Day 21350 lbs/Yr	19.3	7,044	28.2
75 lbs/Day 22875 lbs/Yr	20.1	7,336	29.3
80 lbs/Day 24400 lbs/Yr	20.8	7,592	30.4
85 lbs/Day 25925 lbs/Yr	21.5	7,848	31.4
Dry Cows	9.7	3,540	14.2
Heifers 1 Animal Unit/ 1000 pounds	10.6	3,878	15.5

Each collection system will need to be identified as liquid (gallons), solid, or semi solid (tons). For example, a typical farm may have pack manure from the dry cows (tons), lactating cow manure from a liquid storage (gallons), and heifer manure that is spread daily (semi solid, tons), each from completely different storages, as well as calf manure removed

from hutches (tons). Each manure system should have a sample analysis taken annually that measures organic nitrogen, ammonia nitrogen, phosphate, potash, and dry matter. From this, the total N, P, and K is calculated. The next step is to decide proper application sites, rates, and timing.

The average rate of manure to be applied per acre is calculated by dividing the total waste by the available acreage. Crop nutrient needs are based on rotation, soil sample results, and realistic historical yield. By combining the total nutrients and crop needs, a quantitative analysis can be determined. This analysis will help the planner and grower determine if export of nutrients will be needed (see Example 1).

Example 1 Example of a (Simple) Waste Application Plan

Facts of the Example Farm

- The herd includes 200 Cows (20 are dry) and 100 heifers. The average milk production is 80 lbs and the average heifer weight is 800 pounds.
- The watershed nutrient of concern is nitrogen.
- All the manure is collected in a manure storage. This earthen lagoon measures 50 by 150 ft.
- 1000 yards of sawdust are used per year.
- The parlor and wash use 3 gallons of water per cow per day.
- There are 250 acres of corn, 50 acres of alfalfa/ grass new seedings and 150 acres of alfalfa/ grass. The rotation is 4 yrs. hay and 4 yrs. corn.
- No additional water is coming into the system.
- The average corn silage yield is 20 tons/acre and alfalfa/grass averages 4.5 tons of DM.
- All the soils are well drained with good yield potential.
- Manure sample 26 lbs of total N
  14 lbs of organic N
  12 Ammonia N
  12 lbs Phosphate
  25 lbs Potash

A. Total Estimated Waste (see Table 1)

Number of lactating Cows ------> 180 cows (averaging 80 lbs) * 7592 (gal/yr)	1366560
Dry Cows---> 20 cows * 3540 (gal/yr)	70800
Number of Heifers---->((100 heifers * 800 lbs) / 1000 (lbs/AU)) * 3878 (gal/yr)	310240
Parlor Waste ---> 3 gals * 180 cows *365 days	197100
Bedding ((1000 yards * 27 ft/cu ft. * 12.5 lbs per cu ft)/7.5 v. gal.) *85 % voids	38250
Precipitation (35 inches)- evaporation (5 inches) /12 * 50 * 150 / 7.5 v. Gal	2500

Total Estimated Waste 1,985,450 gals

Average Gallons per acre 4,412 gals

B. Calculation of Manure Rate:

Plan:

- All farm fields within the rotation will receive manure.
- Nitrogen needs are 150 lbs of N, based on 20 ton corn silage yields
- Nitrogen from alfalfa/grass sod (very little legume left in sod before being plowed): 1st yr - 100 lbs, 2nd yr - 40 lbs, 3rd yr - 15 lbs
- Manure will be incorporated within 1 day on all corn fields except fall applications and fields coming from sod.
- Organic N released per season: 1st yr. - 35%, 2nd yr. -12%, and 3rd yr. - 5%.

Calculation of Application Rate for Various Production Years of Corn

Production Yr.	1 st Yr	2nd Yr	3rd Yr	4th Yr
Nitrogen Needs	150	150	150	150
Sod Residual	100	50	20	0
N Starter/ Fertilizer	20	20	20	20
Manure Residual N	0	10	16	17
Balance of N Required	30	90	94	113
Maximum Rate (Gallons) Per Acre	6,122	*7,086	*7,402	**12000

* manure incorporated after one day

**2 applications of manure, 5000 gallons applied in fall and 7000 incorporated in spring.

C. Manure Recommendations based on production year and N balance

Crop	Prod. Year	Acres	Recommended Rate	Total Manure
Corn	1	60	6,000	360,000
Corn	2	65	7,000*	455,000
Corn	3	65	7,000*	455,000
Corn	4	60	12,000**	720,000
				Total 1,990,000

- Manure for first year and 4th year (5000 gallons) corn fields will be applied in the fall.
- Corn after corn fields receive 7,000 gallons applied and incorporated in the spring.
- Manure applied to fourth year corn does not exceed nitrogen needs, however it is being overloaded with phosphorous based on the current year crop uptake. Based on soil sample results, this should provide adequate phosphorus for four years of alfalfa/grass mix. The key to the plan is to have the farm apply manure to every acre in the rotation while keeping phosphorous relatively within balance.
- Historical yield and soil sample information should be considered in determining realistic yield goals for each field.

One issue that is not addressed by the Example Waste Application Plan, but requires attention from the planner is the nutrients being fed to the cow. The total mixed ration that is

fed to the cows can certainly impact the amount of nutrients that are excreted. Lowering the amount of dietary phosphorous from .5 to .38 provides a significant change in waste nutrients being applied to the soils. With this change, a cow will secrete approximately 90 fewer pounds of phosphate per year. Increasing the forage consumption and importing less grain is the key to nutrient cycling, cow health, and increased profits. A reputable nutritionist whose focus is on the farm's bottom line and environmental concerns is crucial to the development and implementation of a nutrient management plan.

Once the amount and composition of the manure is determined, the timing for application must be addressed. Each field must be assessed for the risk of runoff and leaching. Runoff is rated along 4 different risk levels in each of 6 categories; drainage, areas of concentrated flow, slope gradient, slope length, winter access, and neighbor relations (see Table 2). Areas of concentrated flow or hydrologically sensitive areas (HSA) are the most evident environmental problems associated with land application of manure. Fields that are HSA are prone to nutrient runoff that could affect a nearby water body. These sites should receive manure with caution. HSAs are seasonal, only hydrologically active during certain times of the year.

Hydrologically sensitive areas are grouped into 3 main categories:

1. Runoff areas including saturated and open lots or other compacted surfaces prone to concentrated flows to water bodies- Major pollutants from runoff areas include pathogens and soluble P and N.

2. Erodible areas that are prone to being washed- Steep slopes with no cover are likely to have concentrated flow. Pollutants from erosion areas include P and sediments.

3. Groundwater recharge areas near springs and wells with well drained soils- Pollutant threats come mainly from N and pathogens.

Table 2. Estimated Risk to Minimize Impact on Surface Water Quality

Field Characteristic	Risk Level 1	Risk Level 2	Risk Level 3	Risk Level 4
A. Slope gradient Annual crops Perennial Crops	 0-5 % 0-8%	 6-10 % 9-15 %	 10 + % 15 + %	Not applicable
B. Slope length	0-300 ft.	300-500 ft.	500 + feet	Not applicable
C. Flooding frequency	None or rare	occasional	frequent	Not applicable
D. Drainage Class	Well drained	Moderately well drained	Somewhat poorly	Not applicable
E. Areas of concentrated flow	no	no	yes	Not Applicable
F. Winter Access	Unlimited	Sometimes limited	Usually limited	Not Applicable
G. Closeness to neighbors	No problem	No Problem	No Problem	Problem

Best months for spreading based on Risk Level:

Risk Level 1: Year- round

Risk Level 2: Primary - April to December
Secondary - January to December
(If not enough Risk Level 1 fields available.)

Risk Level 3: Mid-April to October

Risk Level 4: Restricted - no spreading

If all factors are determined to be in risk category 1 and the slope is greater than 500 ft., the field is classified in risk category 3 and no manure should be applied during the winter season. If necessary, parts of fields can be broken down through the revised soil loss equation and application timing can be determined for each subdivision according to the 6 factors.

The second factor in determining the timing of manure application is the leaching index and is divided into three categories; low, intermediate, and high. Fields that have high leaching, especially if there is a well nearby, require strict management practices. For example, manure should not be applied during the early fall, unless a cover crop is established to take up the free nitrogen. If additional nitrogen is needed, side dress nitrogen instead of preplant nitrogen should be applied.

Another management concern is pathogens, especially from calf manure, that can pose serious health risks. Separating calf manure from that of other livestock and land applying it to minimal risk fields (fields the likelihood of runoff to streams and other surface waters is low) greatly reduces the risk of water contamination. Another possible control method is to land apply calf manure during times when the chance of runoff is minimal and avoid spreading when the ground is frozen or saturated. Typically, the total amount of manure from calves is minimal compared to the rest of the livestock, yet the danger it can pose warrants extra precautions.

After assessing the risk levels and the leaching index of each field, the planner can determine the size of storage recommended based on cow numbers and plans for future expansion. If necessary, the farmer can expand existing storage or build new facilities that meet current environmental regulations.

Records

In order to show compliance with the written plan, it is crucial that the farmer keeps complete and accurate records. Three areas of primary importance are manure application, yield information, and operation and maintenance of the farmstead systems.

It is imperative that precise manure application records are maintained. These would include the number of loads of manure applied, the rate of application, and the date that it was spread. To insure accuracy, farm staff must be trained in proper calibration of the manure spreading equipment because rates may vary within a given field, as well as between fields. It may also be wise to have farm workers initial the record of work that they completed to encourage accountability.

Accurate yield information is important in developing nutrient management recommendations for each individual field. Although soil sample results play a big part in recommended fertilizer application, it is imperative to know previous yield results. More nutrients can be applied to fields that have shown consistently high yields.

After the farmstead has reached compliance with the environmental standards, it is important to keep all the systems functioning effectively. This may include cleaning gutters, mowing around lagoons, cleaning silage low-flow collection systems, mowing filter strips and diversion ditches, and maintaining fences. These maintenance steps should be completed as frequently as necessary and dates should be recorded with each task accomplished.

The more comprehensive and accurate the farm's records, the easier it is to prove compliance with the comprehensive nutrient management plan. These records also allow the farmer to see which fields might not have received the recommended manure rate and can therefore supplement with fertilizer.

Conclusion

A Comprehensive Nutrient Management plan provides a beneficial situation for both the environment and the farm. The farmer can save on fertilizer costs by utilizing his manure resources through proper timing and accurate application rates. A business plan that addresses environmental issues allows him to stay competitive in a global market. When proper steps are taken to insure that nutrients remain in their designated places, the growing crops benefit and the risk of water contamination is minimal.

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United States Department of Agriculture Soil Conservation Service, Agricultural Waste Management Field Handbook.

Van Hourn, H.H., et al. Dairy Manure Management: *Strategies for Recycling Nutrients to Recover Fertilizer Value and Avoid Environmental Pollution.* Circular 1016. Institute of Food and Agriculture Sciences, University of Florida, Gainesville, December 1991.

APPENDIX K

Town of Easton, MA
Tuesday, June 8, 2021

Chapter 329. Manure and Animal Waste Management

[HISTORY: Adopted by the Board of Health of the Town of Easton 6-9-2003. Amendments noted where applicable.]

GENERAL REFERENCES
Animals — See Ch. **104**.
Disposition of refuse — See Ch. **198**, Art. **I**.
Backyard composting — See Ch. **304**.
Solid waste storage and collection — See Ch. **355**, Art. **I**.

§ 329-1. Effective date.

The regulations shall take effect on June 16, 2003. All other regulations inconsistent with these regulations are repealed as of June 9, 2003.

§ 329-2. Purpose.

The purpose for the manure and waste management regulation is to provide a method for animal owners to handle accumulated manure and other wastes in a safe and sanitary manner. The regulation shall address composting, storage, and removal of manure and other wastes related to the keeping of domestic animals.

§ 329-3. Regulations.

A. All manure and waste generated from domestic animals or the keeping there of shall be stored in contained compost piles or manure storage facilities approved by the Board of Health or its duly appointed agent(s).

B. Manure and waste collected in compost piles shall be treated or covered with earth loam or other suitable material such as used bedding, wood chips, saw dust, and lime in sufficient amounts to eliminate any odor or nuisance.

C. Manure storage facilities shall, at a minimum, be constructed of concrete or other durable material, screened, well ventilated and watertight. The vent pipe shall be designed to prevent the entrance of animals, insects and precipitation.

D. Manure and waste shall be removed from animal shelters or barns based on standard farm practices for the type of animals kept so as not to create a health or nuisance problem as deemed by the Board of Health or its duly appointed agent(s).

E. Manure and waste shall be removed from paddocks and open fields based on standard farm practices, the size of the grounds, type of animals kept and weather. In warmer weather between the months May 1st to September 30th, manure and waste shall be removed more frequently to avoid large accumulations and to avoid health or nuisance problem(s) as deemed by the Board of Health or its duly appointed agent(s).

F. Compost piles and manure storage facilities shall be located in location(s) accessible year round for general maintenance, cleaning, turning over and removing.

G. Compost piles and manure storage facilities shall be located a minimum of 100 feet from all potable well water sources.

H. The property owner, its agent, tenant or any other entity that has control of the manure and waste operation shall not allow drainage from the stockpiled manure and/or waste to flow over or onto abutting property, the public way(s), watercourses or wetlands.

I. Inspections may be performed at any reasonable time by the Board of Health or its duly appointed agent(s), without prior notification.

§ 329-4. Penalties.

The Easton Board of Health is authorized by the Massachusetts General Laws, Chapter 111, Section 31, to impose a fine up to a maximum of $1,000 for violation of any reasonable health regulation. Each day of a continuing violation shall be considered a separate violation.

APPENDIX L

Horsekeeping & Water Quality: A Horse Owner's Guide to Protecting Massachusetts Natural Resources

Best Management Practices for Stables and Pastures

If you own horses, this brochure will show how you can play a part in protecting and cleaning up the Commonwealth's water resources. You will learn a few simple best management practices (BMPs) specifically designed for landowners with horses. Armed with this new information, you can join the thousands of citizens, businesses, and communities working together for a cleaner environment.

Managing Waste and Protecting Water Quality

Manure management is a big challenge for horse owners, especially if you have several animals on a small parcel of land and no way of spreading or utilizing the manure. The following best management practices are designed to keep nutrients and soil out of waterways.

- *Store your manure properly.*
  Do not store unprotected piles of manure in places where runoff may enter streams, or flood waters may wash the manure away. Place a cover or tarp over the pile to keep rainwater out.
  Assistance is available through local conservation districts to design manure storage facilities to protect water quality. These structures usually consist of a concrete pad to protect ground water and a short wall on one or two sides to make manure handling easier.
- *Try Composting.*
  There are many benefits to setting up a small composting facility for your horse wastes. Composted manure makes an excellent pasture and garden fertilizer as long as it is not spread too heavily. What's more, it can be combined with yard waste and non-meat kitchen scraps. Horse owners should have no trouble giving away or selling properly composted horse manure.
- *Establish vegetative covers.*
  A vegetative cover placed around buildings or on steeper slopes can help minimize erosion and absorb nutrients while improving the appearance of your property. In addition to avoiding costlier erosion controls, vegetative covers will provide animals with better traction during wet or icy conditions. Examples of commonly used covers include a combination of grasses, vinca and shrubbery.
- *Keep animals out of streams.*
  Designed stream crossings provide a safe, easy way for horses to ford streams. Fencing encourages horses to use the crossing instead of the streambed to navigate streams. This will allow vegetation to stabilize stream banks and reduce sediment pollution. Contact

your local soil conservation district for assistance in designing crossings and other protection measures for your stream.

- *Manage water carefully*
  Manage water within your pasture to control potential nutrient runoff. This may require diverting surface and roof drainage runoff water away from pastures or paddocks. Also, take care to conserve water. Turn the hose off when shampooing horses instead of letting it run, and turn the water on low when rinsing a horse down.

Keeping your Pasture Green

Paddocks, riding rings, trails, and pastures are continuously disturbed areas, under constant physical stress from horses' hooves. Overgrazed pastures, in particular, expose patches of bare soil that can easily erode. Here are several management practices that can help minimize overgrazing in your pasture and help control erosion.

- *Select pasture sites carefully*
  If you are establishing a new pasture, select a site that is well drained and located on high ground. Avoid flood plains, drainage areas, and tracts with long, steep slopes. Remember, it is illegal to alter wetlands in any way without proper authorization. Contact your local soil conservation district for assistance in selecting an appropriate site.
- *Inspect pastures for problems*
  There are many ways to improve the performance of established pastures. For starters, conduct a visual inspection to pinpoint any existing or potential problems. Correcting erosion problems can sometimes be as simple as stabilizing a hill with railroad ties or moving a gate to high ground. Here are some common problems to look for:
  -Patches of bare ground on slopes
  -Small hills and gullies
  -Sediment accumulations downslope
- *Test your soil*
  Establishing and maintaining a dense, vigorous sod that will withstand the constant trampling of horses is no easy chore. An inexpensive soil test from the Cooperative Extension Service can help you determine the type and amount of fertilizer needed for good pasture growth. This will also help prevent nutrient runoff from over-fertilized pastures and can improve your horse's nutrition. Pasture soil should be tested every two or three years to determine fertilizer and lime needs. A comprehensive fertilizer program can then be developed. Call the Soil Testing Lab at 413-545-2311 at the UMass Cooperative Extension Service to obtain sampling and ordering instructions.
- *Reseed bare ground, rills and gullies*
  Bare areas should be leveled and smoothed as best as possible before seeding. The best time to reseed is either late winter/early spring or late summer. Tall fescue is a good seed choice.
- *Minimize spotty growth*
  Manure clumps are a major cause of spotty pasture growth and reduced grazing. On small parcels, manure should be picked up and removed regularly. Placing a piece of chain-link fence or other drag behind a tractor or truck can also break up manure. In addition to

helping your pasture, breaking up manure piles on a regular basis can reduce parasite infestations.

- *Mow pastures to the proper height.*
  It is well known that horses graze selectively, consuming nutritious, young pasture grasses while leaving mature grasses and weeds to seed and spread. Proper mowing is the best way to control weeds and minimize spotty growth. Bear in mind that pasture grasses do best at about six inches.
- *Switch to rotational grazing*
  Heavily overgrazed pastures offer little feed for horses and may cause colic if soil is ingested while grazing. Moving livestock from one pasture to another during the growing season can minimize overgrazing. In small pastures, horses should be rotated to a fresh area about every two weeks. As a rule, one or two acres of well-managed pasture can support one mature horse during the grazing season with rotation, while four or five acres without rotation will support only one mature horse for the entire grazing season.
- *Set up a paddock system*
  A paddock system works especially well for landowners with limited pasture land (two acres or less). Paddocks or riding rings can be used for turnout when the pasture is excessively wet or dry, or when you want to reseed, fertilize, or rest the pasture. The paddock should be set up on high ground, using stone dust for the foundation. It should be surrounded with a hardy grass and, if possible, a trench to capture runoff. Riding rings, especially those being used as turnout areas, should be lined with a mixture of sand and sawdust to help protect the soil from erosion.

  If you are unable to set up a paddock system, limit pasture grazing to a few hours each day during the hot, dry summer months.

Material Storage Safety Tips

Many of the chemicals found in barns - formaldehyde, paints, hoof oils, and pesticides to name a few - require careful handling and proper disposal. When using these chemicals, be certain to follow these common-sense guidelines:

- Buy only what you need, and use what you buy.
- Treat spills of hoof oils like a fuel spill. Use kitty litter to soak up the oil and dispose in a tightly sealed plastic bag.
- Store pesticides in a locked, dry, well-ventilated area.
- Whenever possible, select less toxic chemicals.
- Protect stored fertilizer, lime, and pesticides from rain and surface water.

The Commonwealth's Horse Country

Typically, when people think of Massachusetts, they think of rocky and sandy shores. But many horses reside in the state, and they can impact not only the rural areas in which they reside, but also the coast throughout a network of streams and rivers that link the two areas together.

With over 60,000 horses, Massachusetts has a significant horse population which can pose a threat to water quality. Soil from eroding pastures and rainwater runoff from unmanaged animal wastes carry bacteria, nutrients, and sediment to tributaries, and eventually the coast. Scientists have identified erosion and rain water runoff from urban, agricultural, and residential areas, as a major threat to the Commonwealth's water bodies.

Protecting our Natural Resources

In 1993, the Massachusetts Department of Environmental Protection developed "A Clean Water Strategy" premised on the protection and management of water resources at the watershed level. In conjunction with this effort, the Executive Office of Environmental Affairs (EOEA) affirmed and broadened this watershed approach to incorporate the expertise and help of other EOEA agencies, such as the Department of Food and Agriculture. This collaboration of state agencies will offer watershed communities exciting opportunities to protect, enhance, and restore water resources within their towns and in cooperation with their watershed neighbors.

Watershed teams will conduct water quality surveys to determine the "health" of the water resources and watershed. This information will be shared with communities, and will lead to better protection and improvement of water quality in the Commonwealth's 27 watersheds.

For more information, or free assistance in planning or implementing the best management practices described in this brochure, contact your local Natural Resources Conservation Service or the UMass Cooperative Extension Service. Working together, we can make a difference in water resource protection in the Commonwealth of Massachusetts.

Agency Resources

Natural Resource Conservation Service (NRCS) works with farmers on issues relating to the best use of our natural resources. Find them in the phone book under federal government, US Department of Agriculture, Natural Resource Conservation Service.

Conservation Districts also work with farmers and livestock owners, often for smaller, non-commercial places, on similar land management assistance.

Natural Resource Conservation Service Centers:
Berkshire CD: 413-443-6867
N.E.N.W., S. Worcester CD: 508-829-6628
Hampden-Hampshire CD: 413-586-5440
Essex-Middlesex-Suffolk CD: 978-692-1904
Bristol-Plymouth-Norfolk CD: 508-295-5151
Cape Cod - Nantucket-Dukes CD: 508-771-6476

UMass Cooperative Extension Service: 413-545-4800

Massachusetts Department of Environmental Protection

Malcolm Harper, 319 Program Coordinator: 508-767-2795 or malcolm.harper@state.ma.us

Massachusetts Department of Environmental Protection
Drinking Water Program
July 2014

Protect Local Drinking Water: Pick Up Your Dog's Waste

Whether you are walking your dog on your own land or on public land, it is important to pick up your dog's waste. The average dog generates ¾ lb. of waste per day. That ¾ lb. contains billions of fecal coliform bacteria. Fecal coliform bacteria can contaminate public and private drinking water supplies and can make people sick. This happens when dog waste is left on the ground and washes down into ground water or it flows with stormwater into rivers and streams that enter public drinking water reservoirs. In addition to illness, this pollution encourages weed growth, algae blooms that can result in taste and odor problems, and fish kills.

Dog waste left on the ground may contain hookworms, roundworms and other parasites that can be spread to adults and children walking barefoot or playing in the grass. Viruses can also spread among dogs in this way.

Bagging dog waste and putting it in the trash is a better idea than leaving it on the ground. Massachusetts trash is sent either to a waste-to-energy facility where it is burned to produce energy or to landfills that have special liners that prevent pollutants from leaving the site.

- Do not leave dog waste on the ground.
- Pick up dog waste with a bag and put it in the trash.
- Do not dispose of dog waste in wetlands, storm drains, or compost piles.
- It is not good practice to locate dog parks near public or private drinking water supplies.

For more information about impacts to drinking water from dog waste, call the MassDEP's Drinking Water Program at 617-292-5770 or e-mail: program.director-dwp@state.ma.us.

APPENDIX M

INSPECTION / EVALUATION REPORT

LOWER ARTICHOKE RESERVOIR DAM (MA00264)

UPPER ARTICHOKE RESERVOIR DAM (MA00189)

INDIAN HILL RESERVOIR DAM & DIKES (MA02280)

Owner:	City of Newburyport Water Works
Town:	Newburyport, Massachusetts
Consultant:	Tighe & Bond, Inc.
Date of Inspection:	July 27, 2020

UNDER SEPARATE COVER

Tighe&Bond

APPENDIX N

Artichoke River - Hydrologic & Hydraulic Analysis

TO: Jon-Eric White, PE, City Engineer (City of Newburyport)

FROM: Christina Wu; David Azinheira, PE, CFM (Tighe & Bond)

COPY: Tracy Adamski, AICP (Tighe & Bond)

DATE: December 9, 2020

A hydrologic and hydraulic (H&H) analysis of the Artichoke River watershed was performed by Tighe & Bond. The primary reasons for performing the H&H analysis were to:

- Evaluate the hydraulics of the City's water supply dams along the Artichoke River in response to upland flooding from the Artichoke River and tailwater flooding from the Merrimack River.
- Evaluate the impact of a breach of the Lower Artichoke Reservoir Dam.

The analysis included:

- A hydrologic analysis of the Artichoke River watershed using USDA-SCS Technical Release No. 20 (TR-20) methodology
- A two-dimensional (2D) hydraulic analysis of the Artichoke River extending from Upper Artichoke Reservoir to the Merrimack River

Appendix A contains a site location map of the site (Figure 1), an aerial imagery map of the site (Figure 2), a site location map of the sub-watersheds (Figure 3), and the 2D mesh used to define the Artichoke River HEC-RAS model (Figure 4). Appendix B contains the hydrologic model output. Appendix C contains the Artichoke River 2D HEC-RAS model output for Lower Artichoke Reservoir Dam.

1 Project Site Description

The City of Newburyport's public drinking water is supplied by three interconnected surface reservoirs, one isolated surface pond, and two groundwater supply wells. The majority of water is supplied from the three interconnected surface reservoirs: Indian Hill Reservoir, Upper Artichoke Reservoir, and Lower Artichoke Reservoir. The Indian Hill Reservoir spills over the Indian Hill Reservoir Dam (NID #MA02280) and flows downstream via a natural stream channel to the Upper Artichoke Reservoir, which is held back by the Upper Artichoke Reservoir Dam (NID #MA00189) that discharges directly into the Lower Artichoke Reservoir. The Lower Artichoke Reservoir Dam (NID #MA00264) consists of a concrete spillway and earthen embankment.

Lower Artichoke Reservoir Dam is located on the Artichoke River; water from Indian Hill Reservoir and Upper Artichoke Reservoir drain by gravity to the Lower Artichoke Reservoir. The intake to the City of Newburyport drinking water system is a pump station located at the Lower Artichoke Reservoir, which pumps the raw water from the three-reservoir system to the water treatment plant located on Spring Lane.

Discharge from the spillway of Lower Artichoke Reservoir Dam flows approximately 0.5 miles to Artichoke River Dam (NID #MA01600), which is privately owned and not part of the water supply system. Discharge from the Artichoke River Dam travel downstream approximately 680 feet to the confluence with the tidally-influenced Merrimack River.

Tighe & Bond performed dam inspections at Lower Artichoke Reservoir Dam, Upper Artichoke Reservoir Dam, and Indian Hill Reservoir Dam (including dikes) and summarized findings in the *Recommendation to Improve Lower Artichoke Reservoir Dam, Upper Artichoke Reservoir Dam, and Indian Hill Reservoir Dam & Dikes* dated July 27, 2020. Information used for this analysis was also provided by a bathymetric and topographic survey that was conducted for the Upper Artichoke, Lower Artichoke and Indian Hill Reservoirs by Hancock Associates dated March 5, 2020.

2 Methodology

Tighe & Bond prepared a hydrologic and hydraulic (H&H) model of the Artichoke River for the purpose of evaluating the storm-related performance of the following water supply reservoirs, owned by the City:

- Upper Artichoke Reservoir Dam (MA00189)
- Lower Artichoke Reservoir Dam (MA00264)

The riverine hydrologic analysis was performed using USDA-SCS TR-20 methodology. Output from this portion of the analysis was used to develop a 2D hydraulic model for the Artichoke River that extends from the Upper Artichoke Reservoir to the Merrimack River. The methods used to develop both the hydrologic and hydraulic analysis are documented in the following sections. The Newburyport Resiliency Committee (NRC) proposed using 6 feet of sea level rise (SLR) in *Recommendation of Sea Level Rise for Newburyport's Waterfront West Technical Report* dated February 2019. The City of Newburyport asked Tighe & Bond to use this SLR value to account for climate change.

2.1 Hydrologic Analysis

2.1.1 Artichoke River

The hydrologic data for the H&H analysis was developed using the HydroCAD stormwater modeling program which is based on the United States Department of Agriculture's Technical Release 20 program (TR-20). The model was developed using information from USGS and GIS mapping, soil characteristics, watershed characteristics, and ground-cover/land-use types within the watershed. The 24-hour precipitation events used in this study were estimated for this location based on the National Oceanic and Atmospheric Administrations (NOAA) Atlas 14 Volume 10 data, which is considered the most up to date for the region.

A range of storm return events were assessed. A Northeast Regional Climate Center (NRCC) Type D storm distribution curve was used to distribute the precipitation total across the 24-hour storm duration. Table 2-1 provides the precipitation amounts used for the various storms analyzed.

TABLE 2-1
24-hr Precipitation Values from the National Oceanic and Atmospheric Administration NOAA Atlas 14

Storm Return Frequency	Precipitation Values from NOAA Atlas 14 (inches)
2-year	3.35
5-year	4.41
10-year	5.30
25-year	6.51
50-year	7.40
100-year	8.38
500-year	11.50

Given the configuration of the drainage area, the upstream watershed was divided into nine sub-drainage areas (i.e. "sub-basins"). The sub-basins were delineated based on the location of the dams along the Artichoke River as well as the location of major road crossings along the river mainstem and its tributaries (Figure 3). The Storey Ave (Route 113) road-stream crossing, located 220 feet downstream of Lower Artichoke Reservoir Dam, was not considered a control point in the hydrologic model but was included in the hydraulic model. Time of concentration was determined using the empirical SCS lag formula method, which is a function of the length of the watershed, the average slope of the watershed, and the SCS curve number (CN). A summary of the hydrologic information for the HydroCAD model input values is presented in Table 2-2.

The geometry of each of the structures/culverts and spillways were gathered from site visits, and the storage volumes were calculated using MassGIS LiDAR data. The spillway elevation of each dam, the top of road elevation of the major road crossings, and the elevation data sources used are presented in Table 2-3.

TABLE 2-2
Sub-basin Characteristics Used in Hydrologic Model

Sub-Basin ID	Downstream Design Point	Drainage Area (acres)	Curve Number	Time of Concentration (hours)
1	Artichoke River Dam	473	63	2.4
2	Lower Artichoke Reservoir Dam	190	79	0.7
3	Upper Artichoke Reservoir Dam	210	71	1.5
4	Middle Road / Plummer Spring Road	427	73	1.2
5	Rogers Street	755	67	3.1
6	Indian Hill Reservoir Dam	548	79	1.6
7	Garden Street	867	72	2.3
8	Turkey Hill Road	318	71	1.5
9	Interstate Route 95	594	71	1.9

TABLE 2-3
Dam and Culvert Geometry

Location	Elevation (feet, NAVD88[1]) Spillway/ Culvert Invert	Dam Crest/ Road Crest	Source
Artichoke River Dam	4.4	11.0	LiDAR & Field Reconnaissance
Storey Ave (Route 113)	-0.5	20.0	Proposed Route 113 Storey Ave over Artichoke River Construction Drawings dated Feb. 5, 1972
Lower Artichoke Reservoir Dam	8.75	±12 (Varies)	Hancock Associates Survey & Bathymetry dated March 5, 2020
Upper Artichoke Reservoir Dam	12.4	14.9	Phase I Inspection/Evaluation Report by AECOM dated Dec. 6, 2018
Middle Road / Plummer Spring Road	2.4	17.9	LiDAR & Field Reconnaissance
Rogers Street	8.0	16.5	LiDAR & Field Reconnaissance
Indian Hill Reservoir	63.2	65.3	Phase I Inspection/Evaluation Report by AECOM dated Dec. 6, 2018
Garden Street	27.8	38.4	LiDAR & Field Reconnaissance
Turkey Hill Road	10.7	18.2	LiDAR & Field Reconnaissance

[1] NAVD88 = North American Vertical Datum of 1988

Peak flows were also calculated through regression analysis using the Zarriello 2017[1] approach available in the USGS Streamstats[2] program. These flow estimates were used as a basis for comparison with the computer design storm flow rates, in addition to the flow rates published in the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) Report for Essex County, Massachusetts.

Peak flows evaluated in the hydrologic analysis were subsequently used as input to the 2D HEC-RAS model as the upstream boundary conditions and were included as four inflow hydrographs. The four inflow hydrograph locations account for flows from sub-basin areas that contribute flow to the Artichoke River. Artichoke River baseflow conditions were included in the 2D HEC-RAS model based on the Ries 2000[3] approach for the 50 percent duration flow.

2.2 Hydraulic Analysis

2.2.1 Terrain Development

Terrain surfaces provide representations of topographic and bathymetric data used to perform hydraulic analyses. The terrain surface for the Artichoke River and Lower Artichoke Reservoir Dam study area was developed by combining existing survey data, available

[1] Zarriello, P.J., 2017, Magnitude of flood flows at selected annual exceedance probabilities for streams in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2016-5156, 99p.
[2] U.S. Geological Survey, 2016 The StreamStats program, online at http://streamstats.usgs.gov, accessed February 6, 2020.
[3] Ries, K.G., III, 2000, Methods for estimating low-flow statistics for Massachusetts streams: U.S. Geological Survey Water Resources Investigations Report 00-4135, 81 p. (http://pubs.usgs.gov/wri/wri004135/)

LiDAR data, and data from available plans. Survey data was provided from the March 5, 2020 and March 13, 2020 topographic and bathymetric survey titled "Existing Conditions Plan Artichoke Reservoir" and "Overall Plan Upper & Lower Artichoke, Indian Hill Reservoirs" prepared by Hancock Associates. 1-meter resolution LiDAR data was acquired from MassGIS and was used to provide elevations for areas that were not included in the Hancock Associates survey. Elevations reference the NAVD88 datum.

The available terrain data from the Hancock Associates survey and the MassGIS LiDAR data did not include bathymetric data for the Merrimack River nor detailed elevations for the road-stream crossings. The bathymetric data adjacent to the roadway crossings and the geometry of the structures were estimated using available drawings. Table 2-3 summarizes the elevations used for the dam and culvert structure elevations, as well as the data source for the listed elevation. Elevations from drawings were converted to the NAVD88 datum.

The bathymetry between Lower Artichoke Reservoir Dam and the Merrimack River was estimated using spot elevations at the dam and MassDOT bridge drawings for Route 113 dated February 1972 combined with LiDAR to interpolate contours between the estimated thalweg and bank elevations to create the stream bottom used for the 2D hydraulic model.

2.2.2 Two Dimensional (2D) HEC-RAS Model Geometry

A hydraulic analysis of the Artichoke River at the Lower Artichoke Reservoir Dam was developed using HEC-RAS, a hydraulic modeling program available from the U.S. Army Corps of Engineers. A 2D model was developed instead of a typical 1D model to more accurately represent flow traveling through the City's water supply reservoirs. The hydraulic model extends from the confluence of the Artichoke River and the Merrimack River to approximately two (2) miles upstream of the confluence with the Merrimack River.

The model geometry used the existing conditions terrain as described in Section 2.2.1. 2D modeling allows flow to move across the x-y plane (laterally and longitudinally) and calculates the cell water surface elevation (vertical water level) and flow of water between cells. For comparison, 1D modeling allows flow to move along the y plane (longitudinally) only. 2D modeling requires what is referred to as a 2D computational mesh (cells located on the x-y plane) that allows flow to move from one mesh cell to another with each cell having elevation data based on the terrain and a Manning's roughness coefficient (Manning's n). The 2D computational mesh was developed with a 20-foot spacing in the area of the dam embankments and 50-foot spacing outside of the study area. Figure 4 shows the 2D computational mesh for existing conditions. The model was run using the time-varying module of the program to represent the attenuation of storm event flows from the Artichoke River watershed down to the Merrimack River.

The structures included in the hydraulic model are as follows: Middle Road, Upper Artichoke Reservoir Dam, Lower Artichoke Reservoir Dam, Storey Ave (Route 113), and the Artichoke River Dam. The geometry for each of these structures was determined based on the data sources listed in Table 2-3. According to the March 2020 Hancock Associates Survey & Bathymetry of Lower Artichoke Reservoir Dam, the crest elevation varies along the length of the embankment; these variations have been incorporated into the hydraulic model.

The Manning's n was determined using the MassGIS 2016 land-use dataset by providing a Manning's n for each land use type. Manning's n values were estimated based on available literature and values used in the DSS WISE Lite model, which was developed by the National Center for Computational Hydroscience and Engineering (NCCHE) and supported by FEMA. Table 2-4 shows the Manning's n values used for each land-use type in this analysis.

TABLE 2-4
Land Use Classification and associated Manning's roughness coefficients (n values)

Land Use Code[1]	Land Use Classification	Manning's roughness coefficient[2] (n value)
2	Impervious	0.02
5	Developed Open Space	0.0404
6	Cultivated Land	0.07
7	Pasture/Hay	0.035
8	Grassland	0.04
9	Deciduous Forest	0.1
10	Evergreen Forest	0.1
12	Scrub/Shrub	0.04
13	Palustrine Forested Wetland (C-CAP)	0.15
14	Palustrine Scrub/Shrub Wetland (C-CAP)	0.05
15	Palustrine Emergent Wetland (C-CAP)	0.1825
16	Estuarine Forested Wetland (C-CAP)	0.15
17	Estuarine Scrub/Shrub Wetland (C-CAP)	0.06
18	Estuarine Emergent Wetland (C-CAP)	0.1825
19	Unconsolidated Shore	0.04
20	Bare Land	0.0113
21	Open Water	0.033
22	Palustrine Aquatic Bed (C-CAP)	0.033
23	Estuarine Aquatic Bed (C-CAP)	0.033

[1]MassGIS 2016 Land Use Dataset
[2]DSS-WISE Lite Manning's n values

The diffusive wave simplification of the Saint Venant Equation was used for hydraulic modeling. The diffusive wave assumes that convective acceleration and local acceleration can be disregarded, which is often a reasonable assumption because the pressure gradient, friction, and gravity are generally an order of magnitude larger[4]. The 2D HEC-RAS model uses an implicit finite volume solution algorithm that computes an elevation volume relationship for each cell, and transfers flow from one cell to the other as flux through the cell faces.

2.2.3 Merrimack River

The confluence of the Artichoke River and the tidally influenced Merrimack River is approximately 0.7 miles downstream of Lower Artichoke Reservoir Dam. The Mean Higher High Water (MHHW) for the Merrimack River was established as 4.53 feet in the North American Vertical Datum of 1988 (NAVD88) using the Buzzards Bay National Estuary Protection Program Interactive Tide Viewer (MHHW occurs twice a day). Sea level rise (SLR) is assumed to be 6 feet based on the *Recommendation of Sea Level Rise for Newburyport's Waterfront West Technical Report* prepared by Newburyport Resiliency Committee's Technical Subcommittee on Sea Level Rise dated February 4, 2019; these values are described in greater detail in Section 2.2.4.

[4]Azinheira, David L., et al. "Comparison of effects of inset floodplains and hyporheic exchange induced by in-stream structures on solute retention." *Water Resources Research* 50.7 (2014): 6168-6190.

The Merrimack River backwater elevations used for this analysis are provided by the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) Report for Essex County, Massachusetts (effective July 19, 2018) for the confluence of the Artichoke River and Merrimack River. Table 2-5 shows the MHHW and Base Flood Elevation (BFE) (100-year frequency storm event) for the Merrimack River as backwater conditions used for this study. The Merrimack River BFE is based on elevated river flows caused by a rainfall event and not by storm surge. Pages from the FEMA FIS report showing the BFE of the Merrimack River at the confluence with the Artichoke River are included as Appendix D.

TABLE 2-5
Downstream Backwater Water Surface Elevations

Backwater Condition	Water Surface Elevation, ft NAVD88	Water Surface Elevation with SLR[3], ft NAVD88
MHHW[1]	4.53	10.53
BFE 100-Year[2]	12.2	18.2

[1]Mean higher high water (MHHW) from Buzzards Bay National Estuary Protection Program Interactive Tide Viewer
[2]From the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for Essex County, Massachusetts Effective July 19, 2018
[3]Recommendation of Sea Level Rise (SLR) of six (6) feet for Newburyport's Waterfront West Technical Report, February 2019

The Essex County FEMA FIS report provides an elevation for the Merrimack River during the base flood but does not include a time varying hydrograph. Tighe & Bond developed a time varying 100-year hydrograph using the USGS Gage 01100500 Merrimack River at Lawrence, MA. A storm event on October 2017 was selected as a representative hydrograph shape to develop a Merrimack River base flood used as the downstream boundary condition in the hydraulic model.

The MHHW hydrograph was developed based on a "typical" tide using the predicted tide on January 16, 2020 that started and ended at approximately the MHHW elevation of the National Oceanic and Atmospheric Administration (NOAA) Tides & Currents Station 8443970 - Boston, MA. The predicted tide was used instead of an observed tide because it is an idealized, smoother curve that is more compatible for hydraulic modeling and reduces instability. A single period was taken and repeated to create a typical tidal distribution. For the purposes of modeling, it was assumed both daily tides were approximately the same. The Sea Level Rise (SLR) scenarios were evaluated by increasing the unit tide by the SLR projection.

The downstream boundary condition was input as a stage hydrograph for the Merrimack River using MHHW level and the FEMA 100-year base flood elevation to represent the tidal condition of the Merrimack River (Table 2-5). These two Merrimack River backwater conditions were evaluated over a range of storm events within the Artichoke River watershed. The Merrimack River MHHW with and without SLR were evaluated for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year storm events, and the Merrimack River BFE with and without SLR was evaluated during baseflow conditions (discussed further in Section 2.2.6).

2.2.4 Sea Level Rise

The Newburyport Resiliency Committee (NRC) proposed using 6 feet of sea level rise (SLR) in *Recommendation of Sea Level Rise for Newburyport's Waterfront West Technical Report* dated February 2019. The City of Newburyport asked Tighe & Bond to use this SLR value to account for climate change.

To account for sea level rise in the 2D hydraulic model following the NRC approach, the downstream stage hydrograph boundary condition was increased by 6 feet at each time step for each SLR scenario.

This approach provides a succinct method to account for SLR; however, we acknowledge that sea level rise on flood elevations is not necessarily linear, and phenomenon including storm surge, high tides, and wave action may be worsened with SLR.

2.2.5 Dam Breach Analysis

Tighe & Bond performed a dam breach analysis using HEC-RAS 2D hydraulic model to evaluate the impacts of a breach at Lower Artichoke Reservoir Dam. The analysis included the Spillway Design Flood (SDF, 50-year) upland flooding conditions from the Artichoke River during MHHW and MHHW+SLR conditions at the Merrimack River as well as baseflow conditions in the Artichoke River under the Merrimack River FEMA BFE condition.

HEC-RAS is used to develop an outflow hydrograph resulting from a breach of a dam, combine that breach hydrograph with the reservoir's inflow hydrograph, and route the results through the downstream valley. The governing equations of the model are the two-dimensional St. Venant equations of unsteady flow coupled with internal boundary equations to represent rapidly varying flow that may occur through structures such as dams, bridges, and roadway embankments. Flow can be subcritical or supercritical and can vary in space and time.

With the unsteady hydraulic model completed as described in previous sections, the following dam breach analyses were modeled:

- 'Wet weather' failure scenario, during which the dam fails during conditions that correspond to the Lower Artichoke Reservoir Dam Spillway Design Flood (SDF) and Merrimack River backwater conditions at mean higher high water (MHHW).
- 'Wet weather' failure scenario, during which the dam fails during conditions that correspond to the Lower Artichoke Reservoir Dam SDF (50-year) and Merrimack River backwater conditions at MHHW plus sea level rise (SLR).
- Merrimack River base flood failure, where the dam fails due to development of internal deficiencies when flows into and out of the impoundment are controlled by a downstream backwater FEMA base flood at the Merrimack River.

Tighe & Bond estimated hypothetical dam failure parameters using the empirical based Embankment Dam Breach Parameters (Froelich, 2008) as described in "Embankment Dam Breach Parameters and their Uncertainties" in the Journal of Hydraulic Engineering. For the wet weather failure and sunny day failures, it was assumed that failure occurs at Lower Artichoke Reservoir Dam when the peak elevation was reached. Table 2-6 provides the dam failure parameters calculated for Lower Artichoke Reservoir Dam.

The dam breach parameters used for the Merrimack River base flood breach scenario were determined based on a comparison of calculated breach parameters resulting from a dam failure due to the impoundment immediately upstream of Lower Artichoke Reservoir Dam (Lower Artichoke Reservoir) or due to the impoundment immediately downstream of Lower Artichoke Reservoir Dam (Artichoke River). The Froelich breach parameters calculated for a breach of Lower Artichoke Reservoir Dam due to the Lower Artichoke Reservoir were more conservative and therefore were used for the dam breach model.

TABLE 2-6
Froelich Dam Failure Parameters for Lower Artichoke Reservoir Dam

Model Run No.	Model Scenario	Final Bottom Width, feet	Side Slope, H:V	Breach Formation Time, hours
Run No. 17	50-Year under MHHW	65.0	1:1	1.17
Run No. 18	50-Year under MHHW+SLR	65.0	1:1	1.17
Run No. 19[1]	Merrimack River FEMA Base Flood	67.6	1:1	1.24
Run No. 19[2] (Not Used)	Merrimack River FEMA Base Flood	*60.1*	*1:1*	*1.05*

[1]Dam failure due to the impoundment immediately upstream of Lower Artichoke Reservoir Dam – Lower Artichoke Reservoir.
[2]Dam failure due to the impoundment immediately downstream of Lower Artichoke Reservoir Dam – Artichoke River.

2.2.6 Model Scenarios

The 2D HEC-RAS model scenarios were developed to assess the impacts of upland flooding resulting from Artichoke River flows and tailwater flooding caused by Merrimack River flows and tidal surge. Upland flooding describes peak flow events in the Artichoke River due to precipitation events. Tailwater flooding describes the water levels of the downstream Merrimack River. The various modeled combinations of upland and tailwater flooding are listed in Table 2-6.

TABLE 2-6
2D HEC-RAS Model Scenarios

Run No.	Artichoke River (Upland Flooding)	Merrimack River (Tailwater Flooding)	Lower Artichoke Reservoir Dam Status
1	2-Year	MHHW[1]	Existing Conditions (no Breach)
2	5-Year		
3	10-Year		
4	25-Year		
5	50-Year		
6	100-Year		
7	500-Year		
8	2-Year	MHHW[1] + SLR[3]	Existing Conditions (no Breach)
9	5-Year		
10	10-Year		
11	25-Year		
12	50-Year		
13	100-Year		
14	500-Year		
15	Baseflow	FEMA BFE[2]	Existing Conditions (no Breach)
16	Baseflow	FEMA BFE[2] + SLR[3]	
17	50-Year	MHHW[1]	Breach
18	50-Year	MHHW[1] + SLR[3]	
19	Baseflow	FEMA BFE[2]	

[1]Mean higher high water (MHHW) from Buzzards Bay National Estuary Protection Program Interactive Tide Viewer
[2]From the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for Essex County, Massachusetts Effective July 19, 2018
[3]Recommendation of Sea Level Rise (SLR) of six (6) feet for Newburyport's Waterfront West Technical Report, February 2019

3 Analysis Results

The H&H models were evaluated for the existing conditions for the Lower Artichoke Reservoir Dam near the confluence of the Artichoke River and Merrimack River. The model results are presented in the following sections.

3.1 Hydrologic Analysis

3.1.1 Artichoke River

Table 3-1 and Figure 3-1 show the peak flow results for the Artichoke River calculated using HydroCAD, Streamstats regression equations, and the available values from the FEMA FIS. The flow rates from the FEMA FIS were scaled based on drainage area from the Upper Artichoke Reservoir Dam to the Lower Artichoke Reservoir Dam. The computed flow rates from HydroCAD are greater than the FEMA FIS and StreamStats flow rates (at Lower Artichoke Reservoir Dam). Uncalibrated rainfall-runoff models often produce more conservative values than regression methods, additionally, the FIS report for Essex County flow rate predictions were computed prior to December 1978 and may be outdated. Calibration of the computed flow rates (i.e., using measured flow rates and rainfall data) may reduce these flows to be less conservative. For the purposes of this analysis, the potentially conservative flows are considered reasonable.

TABLE 3-1

Summary of Predicted Peak Flow Rates for the Artichoke River at Lower Artichoke Reservoir Dam

Storm Recurrence Frequency	HydroCAD Flow Rate (ft^3/s)	StreamStats Flow Estimate (ft3/s)	FEMA FIS* Flow Rate (ft^3/s)	Flow Rate Used for Modeling (ft^3/s)
2-year	208	95.8	-	208
5-year	361	156	-	361
10-year	476	204	88	476
25-year	634	271	-	634
50-year	769	325	199	769
100-year	904	383	265	904
500-year	1,299	531	320	1,299

* Data from FEMA FIS report for Essex County dated July 19, 2018 scaled to the location of the Lower Artichoke Reservoir Dam. FEMA Artichoke River hydrologic modeling was performed prior to December 1978 per the 1978 West Newbury FEMA FIS Report using the SCS graphical method.

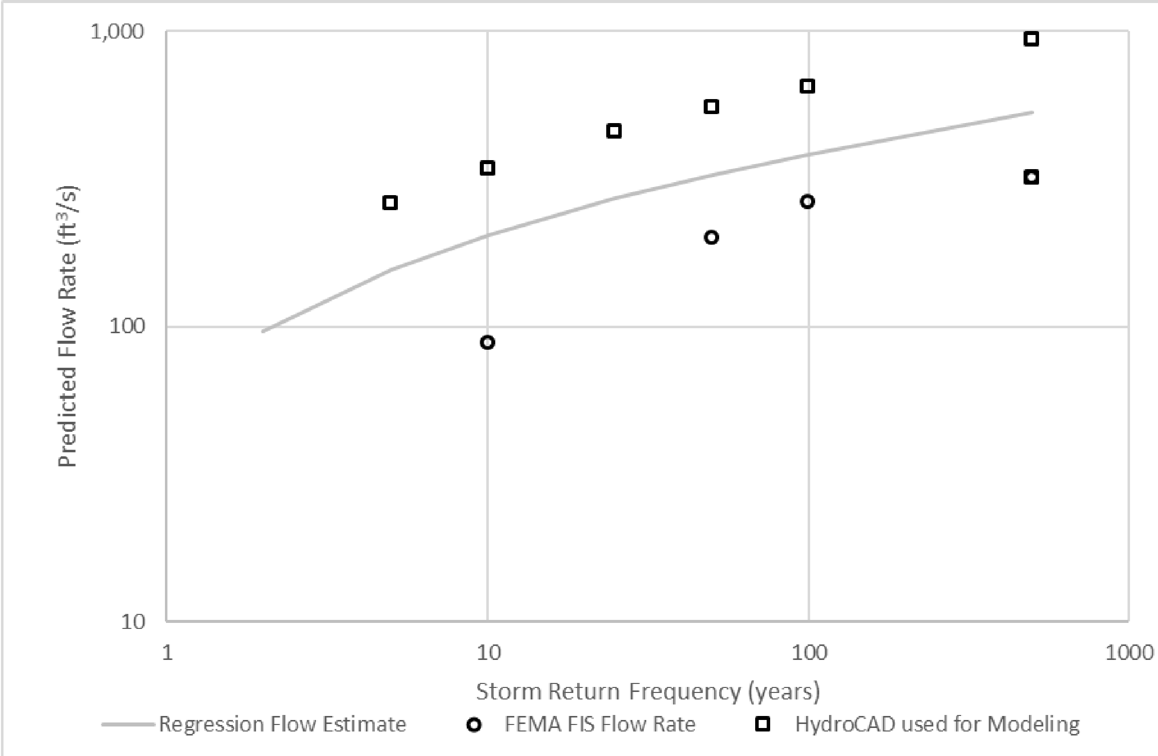


FIGURE 3-1

Summary of Predicted Peak Flow Rates for the Artichoke River at Lower Artichoke Reservoir Dam

3.2 Hydraulic Analysis

3.2.1 Flooding from Artichoke River Watershed

The peak flow rates evaluated in the Artichoke River hydrologic analysis were used as inputs to the 2D HEC-RAS model to evaluate the hydraulics at Lower Artichoke Reservoir Dam for existing conditions during MHHW at the Merrimack River. Appendix C contains the Artichoke River 2D HEC-RAS output for existing conditions.

Table 3-2 and Table 3-3 show the peak water surface elevations computed at Lower Artichoke Reservoir Dam and Upper Artichoke Reservoir Dam for the various storm (Artichoke River upland flooding) events analyzed as well as freeboard to the top of dam. The Lower Artichoke Reservoir Dam embankment is irregular, with a low point in the dam crest at 10.8 feet NAVD88 and a typical elevation greater than approximately 12 feet NAVD88. The lowest point in the right (east) embankment is at 9.4 feet NAVD88; however, high ground at approximate elevation 12 feet NAVD88 separates the area east of the embankment from the Artichoke River downstream of Lower Artichoke Reservoir Dam.

The existing right embankment at Lower Artichoke Reservoir Dam overtops during all Artichoke River upland flooding storm events due to the low point in the embankment. The dam crest adjacent to the spillway overtops during the 25-, 50-, 100-, and 500-year storm events (see Table 3-2). Further upstream, Upper Artichoke Reservoir Dam is anticipated to overtop during the 500-year storm event (see Table 3-3).

If the Lower Artichoke Reservoir Dam embankment had a constant elevation of 14 feet NAVD88, the dam is anticipated to pass the 500-year storm event with 0.7 feet of freeboard; however, the hydraulic model would need to be reevaluated for specific design alternatives to confirm.

TABLE 3-2
Summary of Peak Water Surface Elevation at Lower Artichoke Reservoir Dam during Merrimack River MHHW

Upland Flooding Model Scenario	Peak Water Surface Elevation (feet, NAVD88)	Freeboard to Low Point in Dam Crest: 10.8 ft NAVD88 (feet)	Freeboard to Typical Dam Crest: 12 ft NAVD88 (feet)
2-year	10.0	0.9	2.1
5-year	10.4	0.4	1.6
10-year	10.7	0.1	1.3
25-year	11.2	-0.4	0.8
50-year	11.5	-0.7	0.5
100-year	11.9	-1.1	0.1
500-year	12.9	-2.1	-0.9

TABLE 3-3
Summary of Peak Water Surface Elevation at Upper Artichoke Reservoir Dam during Merrimack River MHHW

Model Scenario	Peak Water Surface Elevation (feet, NAVD88)	Freeboard to Top of Dam (feet)
2-year	13.2	1.7
5-year	13.5	1.4
10-year	13.8	1.2
25-year	14.1	0.8
50-year	14.4	0.5
100-year	14.7	0.2
500-year	15.5	-0.6

3.2.2 Flooding from Merrimack River

The tidal conditions determined for the Merrimack River were based on the FEMA Base Flood Elevation (BFE) listed in the FIS Report for Essex County, Massachusetts and the anticipated sea level rise (SLR) based on the *Recommendation of Sea Level Rise for Newburyport's Waterfront West Technical Report*. These values were used as inputs to the 2D HEC-RAS model as the downstream boundary condition to evaluate the hydraulics at Lower Artichoke Reservoir Dam.

Flooding due to the Merrimack River BFE is anticipated to be from upland flooding from the Merrimack River watershed (i.e. "Merrimack River water"), whereas flooding due to tidal influence from the Merrimack River with SLR (i.e. from the MHHW+SLR) is anticipated to be brackish, including potential coastal storm events occurring at the Merrimack River. Flooding from the Merrimack River BFE+SLR scenario is anticipated to be "Merrimack River water" during the BFE peak, however, would likely be a mix of "Merrimack River water" and brackish water after the BFE peak has passed. Flows from the Artichoke River are assumed to be baseflow during these scenarios with starting elevation levels at approximately the spillway elevation of 8.75 feet NAVD88.

Table 3-4 and Table 3-5 show the peak water surface elevation and freeboard to top of dam computed at Lower Artichoke Reservoir Dam during various storm events in the Artichoke River watershed under MHHW with SLR, and for the FEMA BFE with and without SLR. As previously discussed, the low point in the dam crest is at 10.8 feet NAVD88, and the typical dam crest elevation exceeds 12 feet NAVD88. The spillway elevation is at 8.75 feet NAVD88 and is approximately 2.05 feet below the lowest point in the dam crest and approximately 3.25 feet below the typical dam crest.

Lower Artichoke Reservoir Dam is anticipated to overtop at the dam crest due to backwater from the Merrimack River MHHW with SLR during the 10-, 25-, 50-, 100-, and 500-year storm events in the Artichoke River, while the right embankment overtops during all storm events with MHHW+SLR. It is also anticipated that when the Merrimack River is at the FEMA BFE with and without SLR, Lower Artichoke Reservoir Dam will overtop at the right embankment by a maximum of 8.8 feet and 2.8 feet, respectively. Similarly, Upper Artichoke Reservoir Dam located further upstream, is anticipated to overtop by 3.3 feet when the Merrimack River is at the FEMA BFE + SLR, and by 0.6 feet under MHHW+SLR conditions during Artichoke River baseflow.

During the Lower Artichoke Reservoir Dam 100-year storm event under existing conditions, the spillway is anticipated to overtop by 1.1 feet due to upland flooding from the Artichoke River (Table 3-2). However, the estimated 6 feet of SLR results in potential impacts to drinking water quality due to brackish water entering the reservoir from backwater from the Merrimack River (Table 3-6). Lower Artichoke Reservoir is anticipated to receive approximately 21.17 MG (32.9% of normal pool volume) of brackish water from the Merrimack River during the 100-year storm event under SLR conditions.

TABLE 3-4
Summary of Peak Water Surface Elevation at Lower Artichoke Reservoir Dam during MHHW+SLR Flooding from Merrimack River

Upland Flooding Condition	Tailwater Flooding Condition	Peak Water Surface Elevation (feet, NAVD88)	Freeboard to Low Point in Dam Crest: 10.8 ft NAVD88 (feet)	Freeboard to Typical Dam Crest: 12 ft NAVD88 (feet)
2-year	MHHW[1] + SLR[2]	10.6	0.2	1.4
5-year	MHHW[1] + SLR[2]	10.7	0.1	1.3
10-year	MHHW[1] + SLR[2]	10.9	-0.1	1.1
25-year	MHHW[1] + SLR[2]	11.2	-0.4	0.8
50-year	MHHW[1] + SLR[2]	11.5	-0.7	0.5
100-year	MHHW[1] + SLR[2]	11.9	-1.1	0.1
500-year	MHHW[1] + SLR[2]	12.9	-2.1	-0.9
Baseflow	FEMA BFE[3]	12.2	-1.4	-0.2
Baseflow	FEMA BFE[3] + SLR[2]	18.2	-7.4	-6.2

[1]Mean higher high water
[2]Sea level rise
[3]Federal Emergency Management Agency Base Flood Elevation

TABLE 3-5
Summary of Peak Water Surface Elevation at Upper Artichoke Reservoir Dam during MHHW+SLR Flooding from Merrimack River

Upland Flooding Condition	Tailwater Flooding Condition	Peak Backflow (cfs)	Peak Water Surface Elevation (feet, NAVD88)	Freeboard to Top of Dam: 14.9 ft NAVD88 (feet)
2-year	MHHW[1] + SLR[2]	-	13.0	2.0
5-year	MHHW[1] + SLR[2]	-	13.5	1.4
10-year	MHHW[1] + SLR[2]	-	13.8	1.2
25-year	MHHW[1] + SLR[2]	-	14.1	0.8
50-year	MHHW[1] + SLR[2]	-	14.4	0.5
100-year	MHHW[1] + SLR[2]	-	14.7	0.2
500-year	MHHW[1] + SLR[2]	-	15.5	-0.6
Baseflow	FEMA BFE[3]	-	12.4	2.5
Baseflow	FEMA BFE[3] + SLR[2]	-1,371[4]	18.2	-3.3

[1]Mean higher high water
[2]Sea level rise
[3]Federal Emergency Management Agency Base Flood Elevation
[4]Backflow volume under this scenario is 274 million gallons over 72 hours (of 2D HEC-RAS hydraulic model simulation time) which is approximately 143% of normal pool volume; this is the only scenario in which Upper Artichoke Reservoir Dam overtops due to backwater.

TABLE 3-6
Lower Artichoke Reservoir Dam - Summary of Backwater Inflow during Flooding from Merrimack River

Upland Flooding Condition	Tailwater Flooding Condition	Peak Backflow (cfs)	Backflow Volume Over 72[4] Hours (MG)	Percent of Normal Pool Volume
2-year	MHHW[1] + SLR[2]	-471	21.2	33.0%
5-year	MHHW[1] + SLR[2]	-471	21.2	33.0%
10-year	MHHW[1] + SLR[2]	-471	21.2	33.0%
25-year	MHHW[1] + SLR[2]	-471	21.2	33.0%
50-year	MHHW[1] + SLR[2]	-471	21.2	33.0%
100-year	MHHW[1] + SLR[2]	-471	21.2	32.9%
500-year	MHHW[1] + SLR[2]	-471	21.1	32.9%
Baseflow	FEMA BFE[3]	-515	55.9	86.9%
Baseflow	FEMA BFE[3] + SLR[2]	-3,812	720.1	>100%

[1]Mean higher high water
[2]Sea level rise
[3]Federal Emergency Management Agency Base Flood Elevation
[4]72 hours of 2D HEC-RAS hydraulic model simulation time

3.3 Dam Breach Analysis

Using the methods and input data discussed in Section 1.3, HEC-RAS was used to predict dam failure development and route the resulting flood wave through the downstream 2D Mesh area representing the Artichoke River. HEC-RAS predicts numerous flood wave parameters including water surface elevation, discharge, and the maximum extents of the resulting inundation area. Results from the 2D HEC-RAS model are summarized in Appendix C.

The results indicated that a breach of Lower Artichoke Reservoir Dam during the SDF (50-year) under MHHW would not inundate roads or residences downstream. A failure of the dam during the SDF under MHHW with SLR or during the FEMA BFE would not inundate roads or residences downstream; however, brackish water from the Merrimack River is anticipated to enter the reservoir during the breach and no breach scenarios. The characteristics of the flood wave as a result of a dam failure are provided in Table 3-7, Table 3-8, and Table 3-9 and assume that the Artichoke River Dam is the end of the inundation extent due to its proximity to the confluence with the Merrimack River.

Figure 5, 6, and 7 show the inundation areas for the SDF (50-year) during MHHW at the Merrimack River, the SDF during MHHW with SLR, and the FEMA BFE event, and are provided in Appendix A.

TABLE 3-7
Lower Artichoke Reservoir Dam Failure Results - 50-Year Storm Event under MHHW

Location	Peak Water Surface Elevation (feet, NAVD88)		Peak Backflow (cfs)		Backflow Volume in 72[4] Hours (MG)	
Lower Artichoke Reservoir Breach Status	*No Breach*	*Breach*	*No Breach*	*Breach*	*No Breach*	*Breach*
Upper Artichoke Reservoir Dam[1]	14.4	14.4	-	-	0.0	0.0
Lower Artichoke Reservoir Dam[2]	11.5	11.5	-	-	0.0	0.0
Route 113 - Storey Ave[3]	9.6	10.2	-	-	0.0	0.0

[1]Top of dam is 14.9 feet NAVD88
[2]Low point in dam crest is 10.8 feet NAVD88; low point in right embankment is 9.4 feet NAVD88
[3]Top of road is 20.5 feet NAVD88
[4]72 hours of 2D HEC-RAS hydraulic model simulation time, 43.5 hours after breach

TABLE 3-8
Lower Artichoke Reservoir Dam Failure Results - Dam Breach During 50-Year Storm Event under MHHW and SLR

Location	Peak Water Surface Elevation (feet, NAVD88)		Peak Backflow (cfs)		Backflow Volume in 72[4] Hours (MG)	
	No Breach	*Breach*	*No Breach*	*Breach*	*No Breach*	*Breach*
Upper Artichoke Reservoir Dam	14.4	14.4	-	-	0.00	0.00
Lower Artichoke Reservoir Dam	11.5	11.5	-471	-794	21.2[5]	57.0[6]
Route 113 - Storey Ave	10.9	10.7	-471	-903	25.4	74.9

[1]Top of dam is 14.9 feet NAVD88
[2]Low point in dam crest is 10.8 feet NAVD88; low point in right embankment is 9.4 feet NAVD88
[3]Top of road is 20.5 feet NAVD88
[4]72 hours of 2D HEC-RAS hydraulic model simulation time, 43.5 hours after breach
[5]Approximately 33.0% of Lower Artichoke Reservoir Normal Pool Volume
[6]Approximately 88.6% of Lower Artichoke Reservoir Normal Pool Volume

TABLE 3-9
Lower Artichoke Reservoir Dam Failure Results - Dam Breach During Merrimack River FEMA Base Flood Event

Location	Peak Water Surface Elevation (feet, NAVD88)		Peak Backflow (cfs)		Backflow Volume in 72[4] Hours (MG)	
	No Breach	*Breach*	*No Breach*	*Breach*	*No Breach*	*Breach*
Upper Artichoke Reservoir Dam	12.4	12.4	-	-	0.00	0.00
Lower Artichoke Reservoir Dam	12.2	12.2	-515	-515	55.9[5]	62.8[6]
Route 113 - Storey Ave	12.2	12.2	-550	-550	62.9	64.9

[1]Top of dam is 14.9 feet NAVD88
[2]Low point in dam crest is 10.8 feet NAVD88; low point in right embankment is 9.4 feet NAVD88
[3]Top of road is 20.5 feet NAVD88
[4]72 hours of 2D HEC-RAS hydraulic model simulation time, 41.3 hours after breach
[5]Approximately 86.9% of Lower Artichoke Reservoir Normal Pool Volume
[6]Approximately 97.8% of Lower Artichoke Reservoir Normal Pool Volume

4 Summary

The H&H analysis methodology and results described illustrate existing and potential future risks to Lower Artichoke Reservoir.

Conclusions from the hydraulic analysis for Lower Artichoke Reservoir Dam on the Artichoke River include:

- The peak water surface elevation anticipated during the 50-year frequency storm event, which is the dam's regulatory Spillway Design Flood (SDF) is 11.5 feet NAVD88 during MHHW Merrimack River tidal conditions with and without incorporating for Sea Level Rise. This flood depth overtops the low point in the dam crest by 0.7 feet. The lowest point in the right embankment is 9.4 feet NAVD88; however, high ground at approximate 12 feet NAVD88 separates the area east of the embankment from the Artichoke River downstream of Lower Artichoke Reservoir Dam under this scenario.

  - A dam failure during the 50-year frequency storm event during MHHW Merrimack River tidal conditions would not inundate downstream roads or residences. The reservoir would not be anticipated to be impacted by typical tides; however, would be more susceptible to subsequent flooding of the Merrimack River.

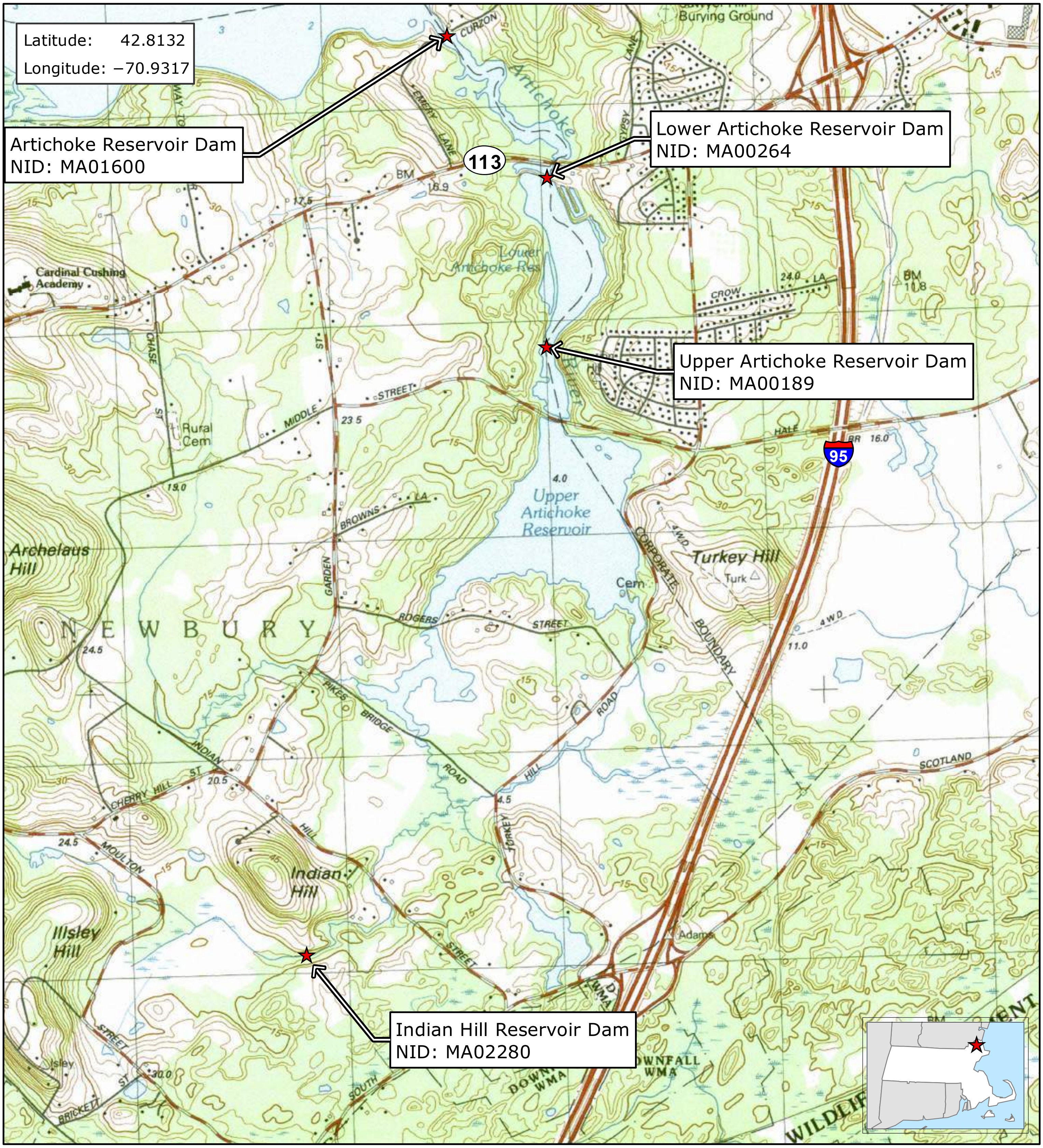
- The peak water surface elevation anticipated during the Artichoke River 50-year SDF with Merrimack River MHHW plus Sea Level Rise (SLR) tidal conditions would cause backwater to enter the reservoir at the low points along the dam crest and embankment, resulting in an estimated 21.2 MG of Merrimack River water over 72 hours (corresponding with approximately 33 percent of the normal pool reservoir volume).
  - A dam failure during the 50-year SDF during Merrimack River MHHW plus SLR tidal conditions would not inundate downstream roads or residences. Water quality in the Lower Artichoke Reservoir may be impacted due to water from the Merrimack River entering through the low areas along the dam crest and embankment and through the dam breach itself, resulting in approximately 57.0 MG of Merrimack River water over 72 hours entering the reservoir (corresponding with approximately 89 percent of the normal pool reservoir volume).
- If a base flood occurred at the Merrimack River an estimated 55.9 MG of Merrimack River water would enter Lower Artichoke Reservoir over 72 hours (corresponding with approximately 87 percent of the normal pool reservoir volume). If a base flood incorporating sea level rise occurred at the Merrimack River, an estimated 720.1 MG of Merrimack River water would enter Lower Artichoke Reservoir over 72 hours (corresponding with approximately 1,120 percent of the normal pool reservoir volume).
- A dam failure during the base flood at the Merrimack River would impact water quality in the Lower Artichoke Reservoir due to water from the Merrimack River entering over the dam, spillway, and breach, resulting in approximately 62.9 MG of Merrimack River water over 72 hours entering the reservoir (corresponding with approximately 98 percent of the normal pool reservoir volume).
  - A breach during the Merrimack River base flood is not anticipated to significantly increase mixing of Merrimack River water compared to a base flood of the Merrimack River occurring without a breach because the peak breach flow would be limited by similar water levels expected on both sides of the dam due to backwater from the Merrimack River; however, the reservoir would be more susceptible to subsequent flooding of the Merrimack River.
- A dam failure would increase the potential for tidal impacts from the Merrimack River, including during the assumed MHHW with SLR scenario that would be anticipated to overtop the dam spillway twice a day.

These results will be used in the various system improvement analyses with the ultimate goal of minimizing potential threats to the source water system. The alternatives will be reviewed with the City with advantages and disadvantages presented.

List of Appendices:

Appendix A – Figures
Appendix B – Artichoke River Hydrologic Modeling Outputs
Appendix C – Hydraulic Analysis Two-Dimensional (2D) HEC-RAS Model Results
Appendix D – Pages from FEMA Flood Insurance Study (FIS)

APPENDIX A
Figures



1:24,000 1 in = 2,000 ft

0 1,000 2,000

Feet

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Based on USGS Topographic Map for Newburyport West, MA Revised 1985. Contour Interval Equals 3-Meters.

FIGURE 1

USGS SITE LOCUS MAP

Artichoke Reservoir Dam (MA01600)
Lower Artichoke Reservoir Dam (MA00264)
Upper Artichoke Reservoir Dam (MA00189)
Indian Hill Reservoir Dam (MA02280)
Newburyport, Massachusetts

November 2020

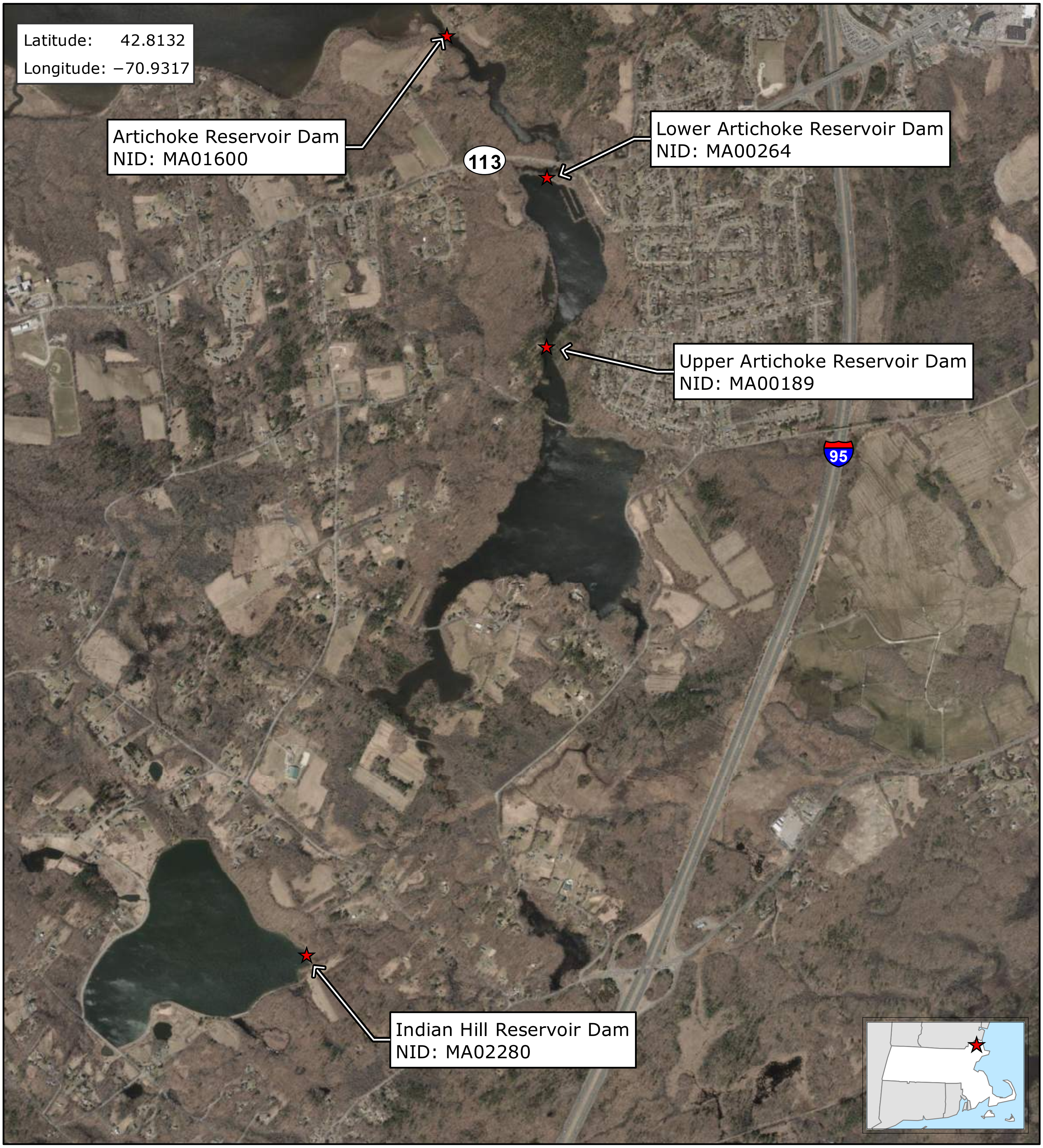


FIGURE 2
ORTHOPHOTOGRAPH

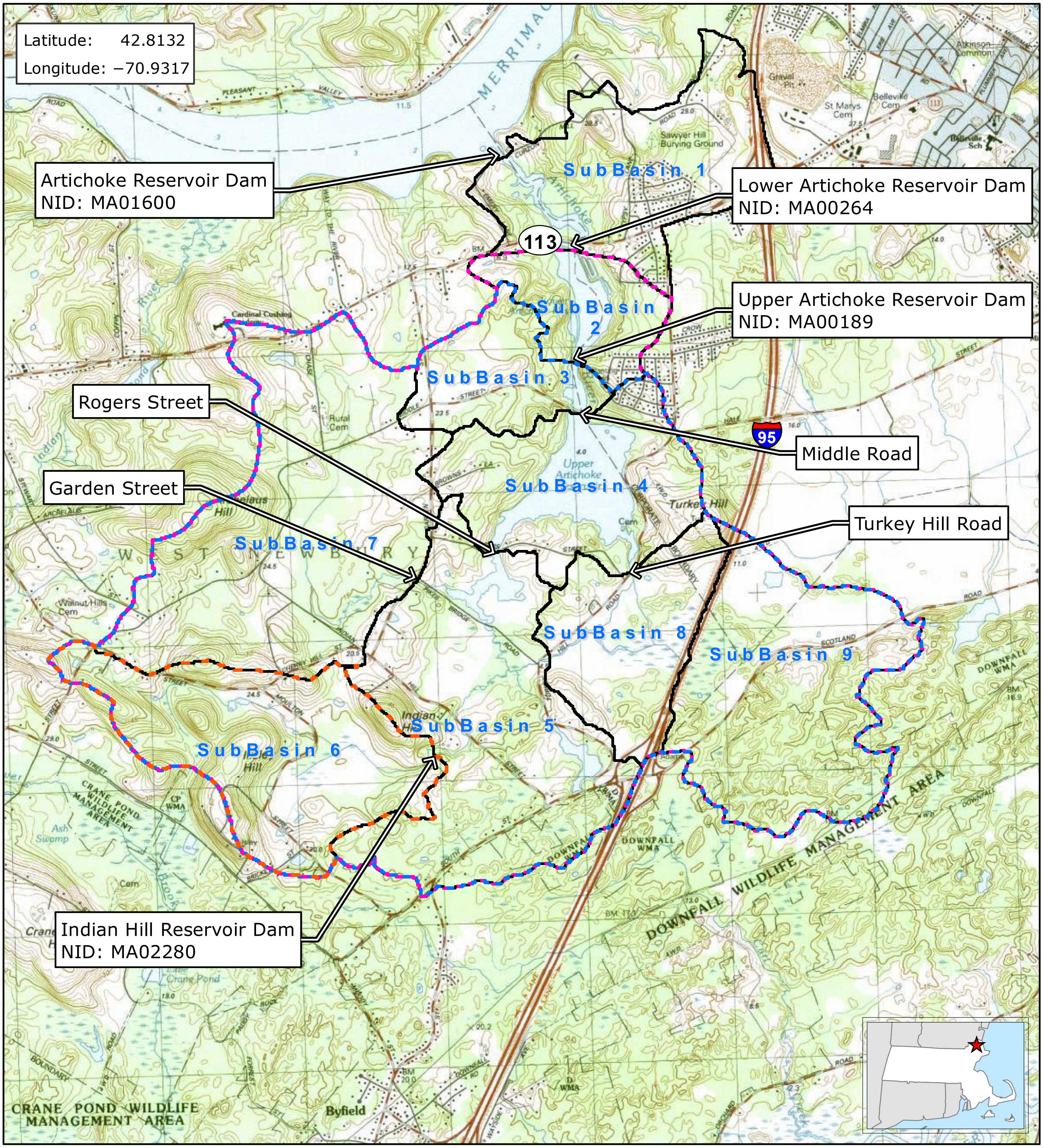
Artichoke Reservoir Dam (MA01600)
Lower Artichoke Reservoir Dam (MA00264)
Upper Artichoke Reservoir Dam (MA00189)
Indian Hill Reservoir Dam (MA02280)
Newburyport, Massachusetts
November 2020

1:24,000 1 in = 2,000 ft
0 1,000 2,000
Feet

Tighe&Bond
Engineers | Environmental Specialists

Based on MassGIS Color Orthophotography (2019)

\\tighebond.com\data\Data\Projects\N\N5059 Newburyport MA\001 Watershed Protection\Drawings_Figures\GIS\Figures\H&H Report Figures\Dam_Aerial.mxd [Exported By: CYWu, 11/29/2020, 6:49:14 PM]



Legend

- Indian Hill Reservoir Dam Watershed Boundary
- Upper Artichoke Reservoir Dam Watershed Boundary
- Lower Artichoke Reservoir Dam Watershed Boundary
- Sub-Basins

Tighe&Bond
Engineers | Environmental Specialists

Based on USGS Topographic Map for Newburyport West, MA Revised 1985. Contour Interval Equals 3-Meters.

1:36,000 1 in = 3,000 ft

0 1,000 2,000 3,000

Feet

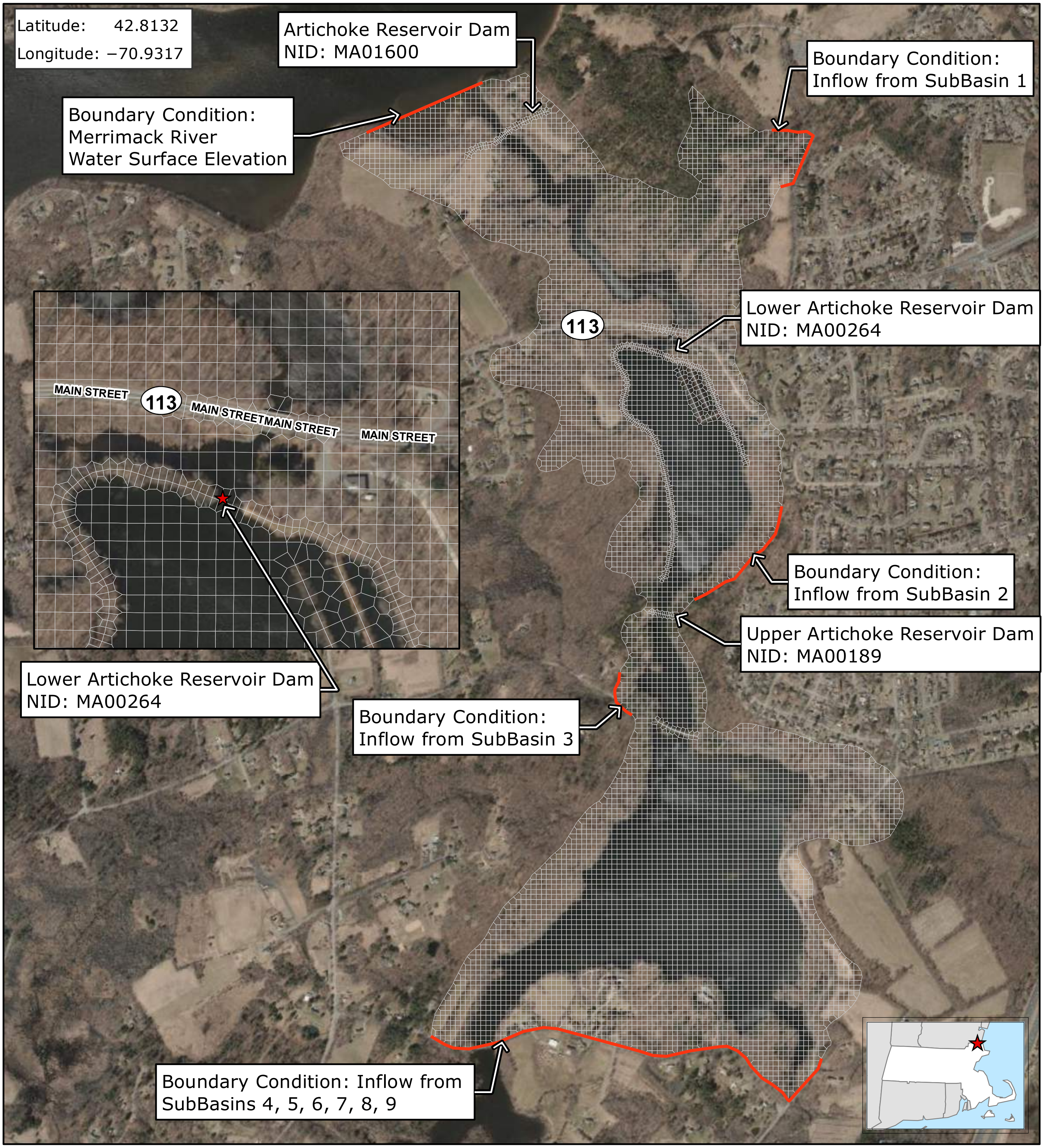
N

FIGURE 3

WATERSHED AREAS

Artichoke Reservoir Dam (MA01600)
Lower Artichoke Reservoir Dam (MA00264)
Upper Artichoke Reservoir Dam (MA00189)
Indian Hill Reservoir Dam (MA02280)
Newburyport, Massachusetts

November 2020



Legend

HEC-RAS 2D Boundary Conditions

HEC-RAS 2D Mesh

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Based on MassGIS Color Orthophotography (2019)

1:15,600 1 in = 1,300 ft

0 650 1,300

Feet

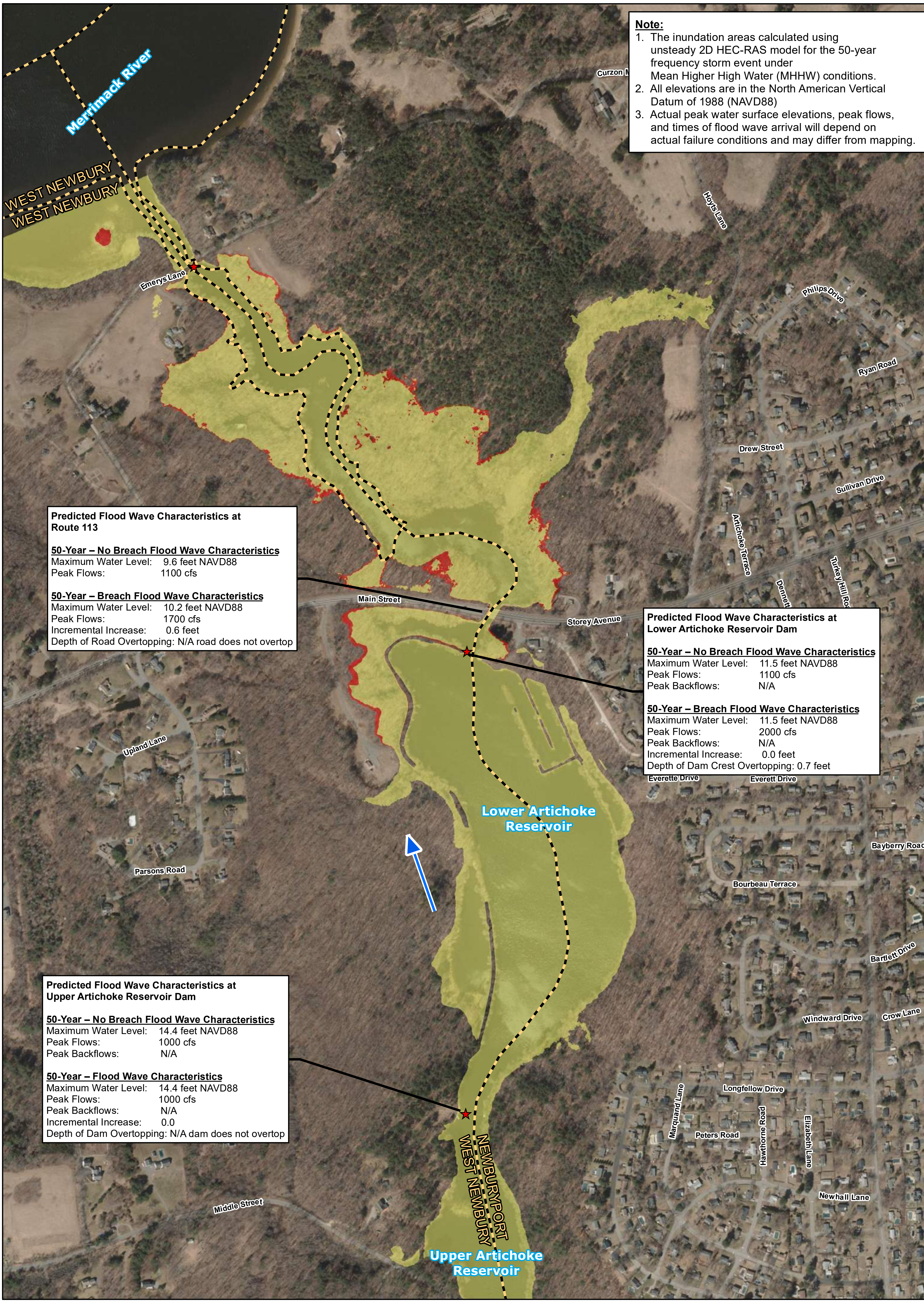
N

FIGURE 4
HEC-RAS 2D MESH & BOUNDARY CONDITIONS

Lower Artichoke Reservoir Dam (MA00264)
Upper Artichoke Reservoir Dam (MA00189)

Newburyport, Massachusetts

November 2020



LEGEND

- SDF Inundation Area (No Breach)
- SDF Breach Inundation Area
- Municipal Boundary
- Flow Direction

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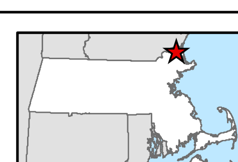
Based on MassGIS Color Orthophotography (2019).



1 in = 500 ft

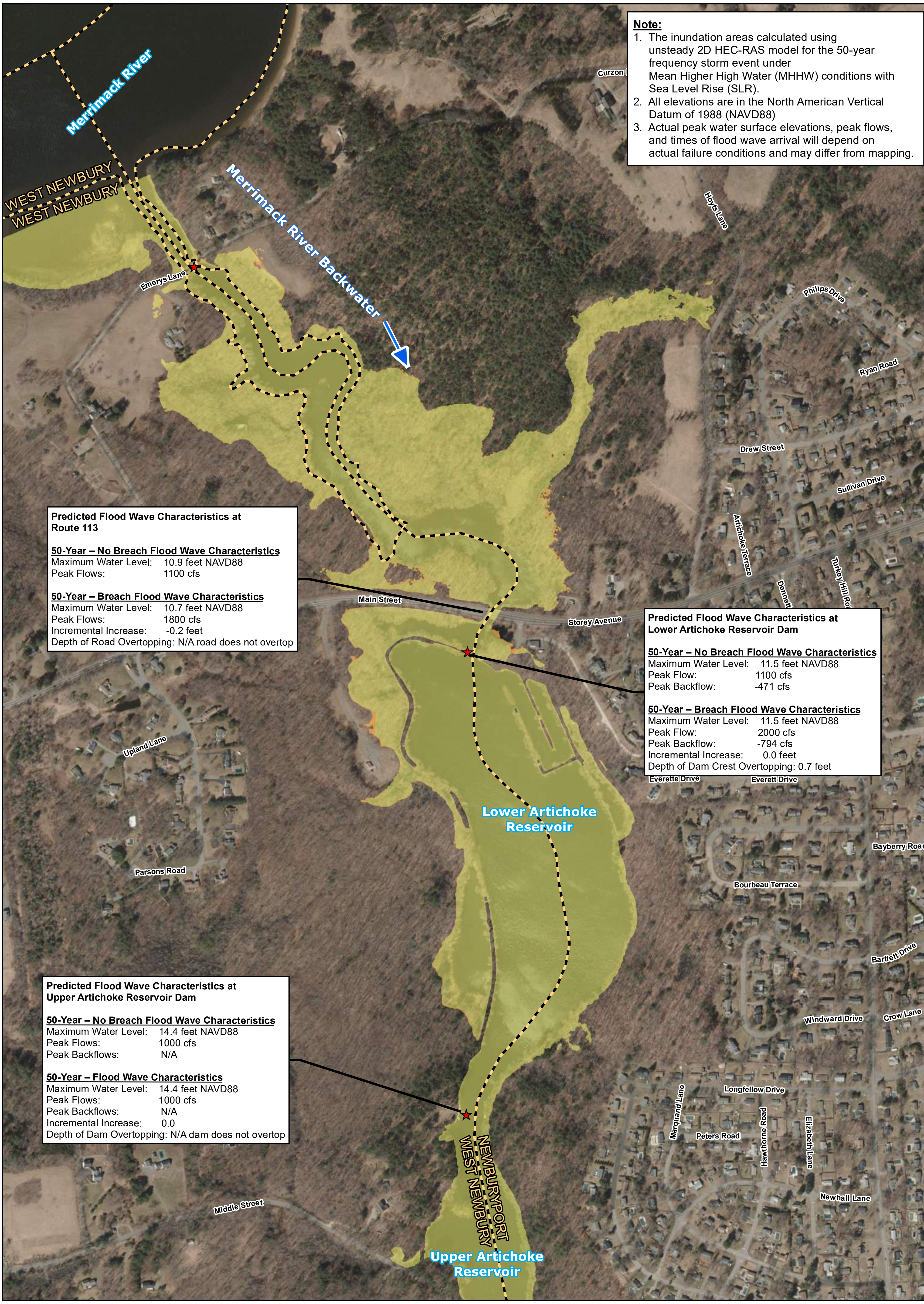
0 250 500
Feet

FIGURE 5
50-YEAR STORM
MHHW
INUNDATION AREAS
Lower Artichoke Reservoir Dam
MA Dam #MA00264
Newburyport, Massachusetts

November 2020

\\tighebond.com\data\Data\Projects\N\N5059 Newburyport MA\001 Watershed Protection\Drawings_Figures\GIS\Figures\H&H Report Figures\LARD_Inundation_50year_MHHW.mxd

N-5059



LEGEND

- SDF Inundation Area (No Breach)
- SDF Breach Inundation Area
- Municipal Boundary
- Flow Direction

Tighe&Bond
Engineers | Environmental Specialists

Based on MassGIS Color Orthophotography (2019).

1 in = 500 ft

0 250 500
Feet

FIGURE 6
50-YEAR STORM
MHHW + SLR
INUNDATION AREAS

Lower Artichoke Reservoir Dam
MA Dam #MA00264
Newburyport, Massachusetts

December 2020

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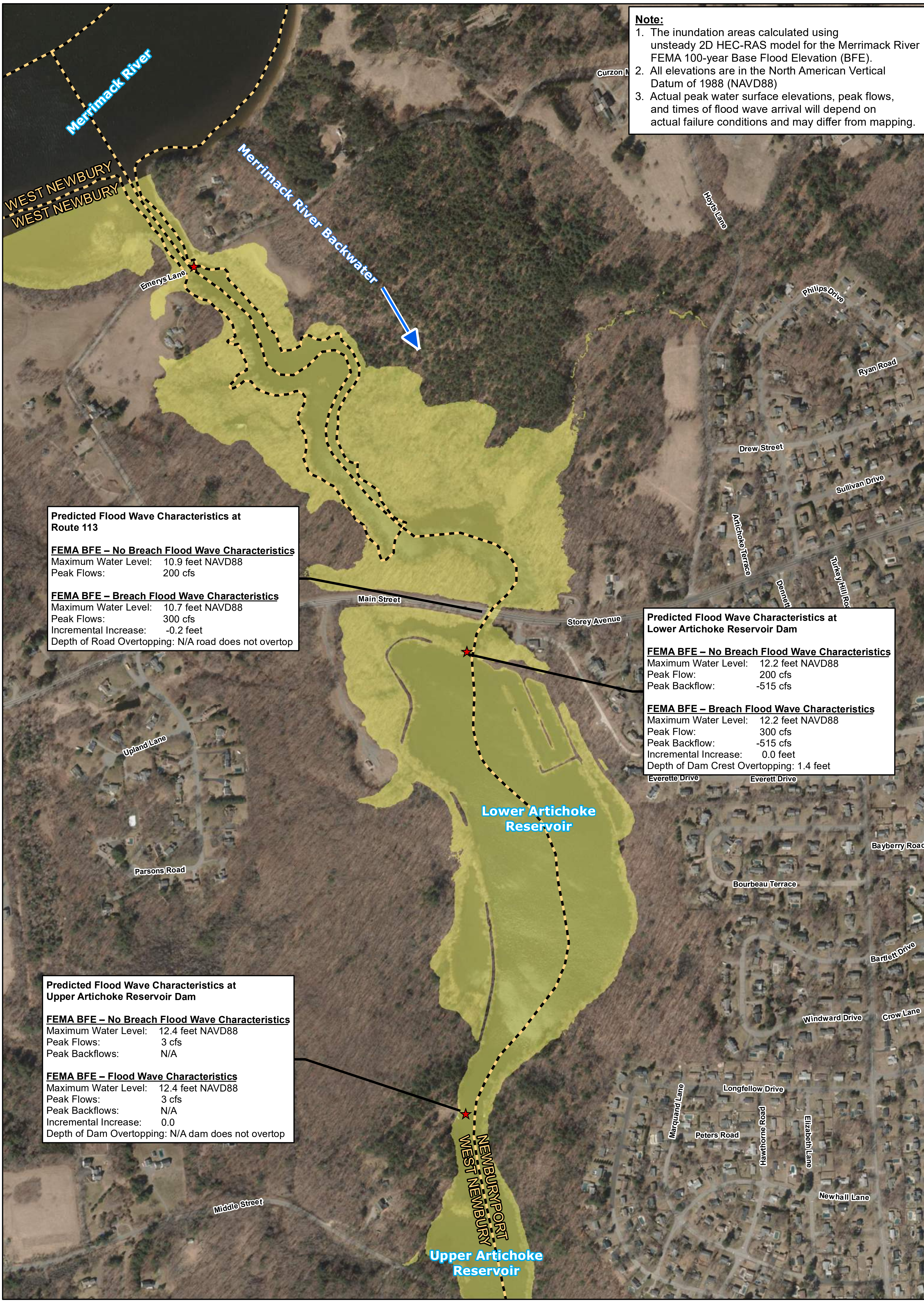
N-5059



LEGEND

- Merrimack River FEMA BFE Inundation Area (No Breach)
- Merrimack River FEMA BFE Breach Inundation Area
- Municipal Boundary
- Flow Direction

Tighe&Bond
Engineers | Environmental Specialists

Based on MassGIS Color Orthophotography (2019).

1 in = 500 ft

0 250 500
Feet

FIGURE 7
MERRIMACK RIVER FEMA BASE FLOOD ELEVATION INUNDATION AREAS

Lower Artichoke Reservoir Dam
MA Dam #MA00264
Newburyport, Massachusetts

December 2020

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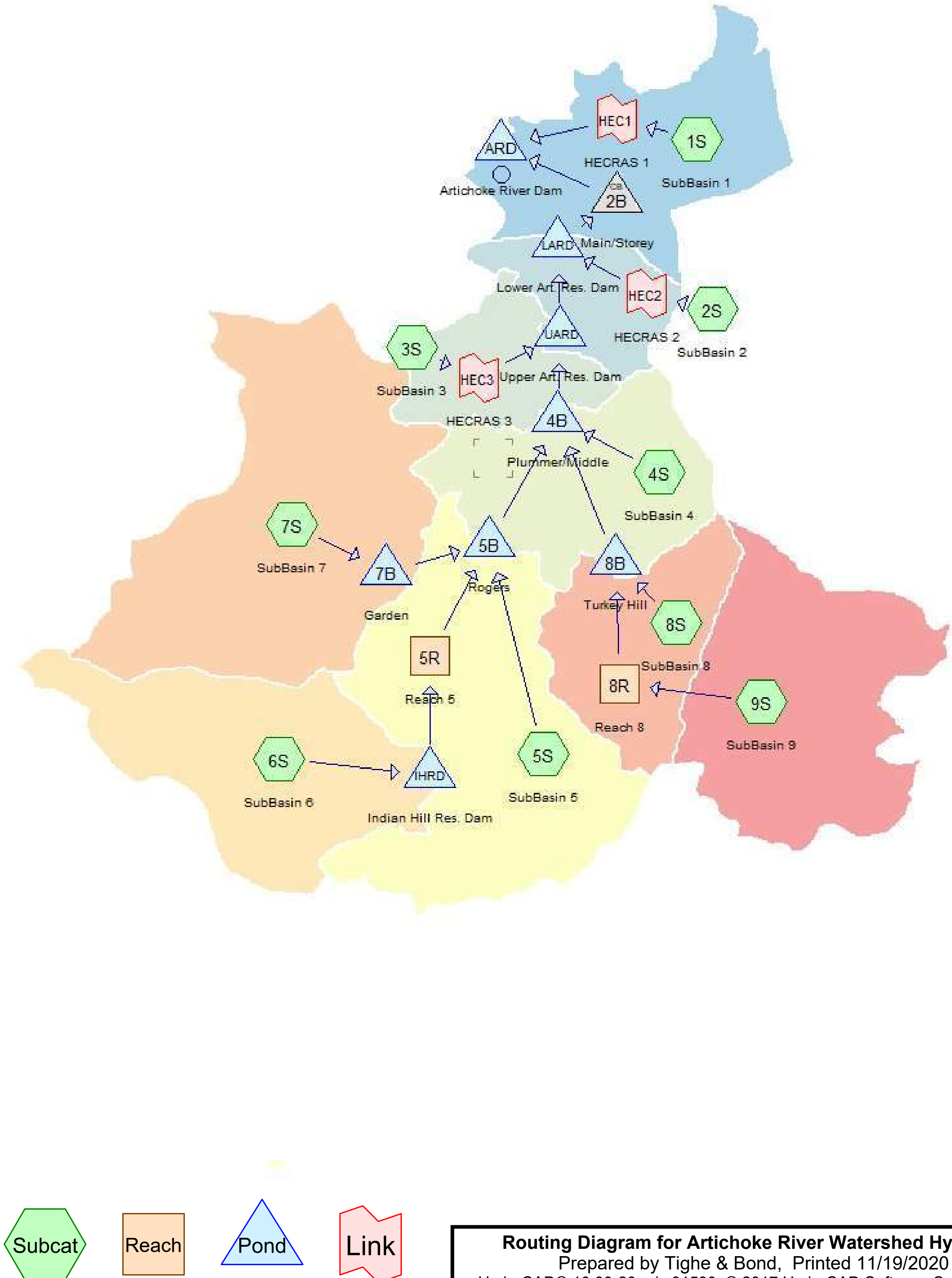
N-5059

APPENDIX B

Hydrologic Modeling Outputs



Routing Diagram for Artichoke River Watershed Hydrology
Prepared by Tighe & Bond, Printed 11/19/2020
HydroCAD® 10.00-20 s/n 01580 © 2017 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
473.452	63	(1S)
189.875	79	(2S)
210.360	71	(3S)
426.626	73	(4S)
754.731	67	(5S)
547.559	79	(6S)
867.188	72	(7S)
318.468	71	(8S)
593.693	71	(9S)
4,381.952	**71**	**TOTAL AREA**

Soil Listing (all nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
0.000	HSG B	
0.000	HSG C	
0.000	HSG D	
4,381.952	Other	1S, 2S, 3S, 4S, 5S, 6S, 7S, 8S, 9S
4,381.952		**TOTAL AREA**

Ground Covers (all nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
0.000	0.000	0.000	0.000	4,381.952	4,381.952		1S, 2S, 3S, 4S, 5S, 6S, 7S, 8S, 9S
0.000	**0.000**	**0.000**	**0.000**	**4,381.952**	**4,381.952**	**TOTAL AREA**	

Pipe Listing (all nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)	Inside-Fill (inches)
1	4B	2.40	2.40	18.0	0.0000	0.025	168.0	151.2	0.0
2	5B	8.00	8.00	25.0	0.0000	0.025	102.0	78.0	0.0
3	7B	27.80	27.70	30.0	0.0033	0.012	48.0	0.0	0.0
4	8B	10.70	10.60	25.0	0.0040	0.013	102.0	66.0	0.0
5	IHRD	54.20	38.70	107.6	0.1441	0.012	48.0	0.0	0.0

Time span=0.00-72.00 hrs, dt=0.01 hrs, 7201 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment1S: SubBasin 1 Runoff Area=473.452 ac 0.00% Impervious Runoff Depth=3.20"
Flow Length=9,407' Slope=0.0452 '/' Tc=144.0 min CN=63 Runoff=333.48 cfs 126.386 af

Subcatchment2S: SubBasin 2 Runoff Area=189.875 ac 0.00% Impervious Runoff Depth=4.95"
Flow Length=3,690' Slope=0.0466 '/' Tc=43.1 min CN=79 Runoff=439.72 cfs 78.353 af

Subcatchment3S: SubBasin 3 Runoff Area=210.360 ac 0.00% Impervious Runoff Depth=4.06"
Flow Length=6,567' Slope=0.0455 '/' Tc=87.2 min CN=71 Runoff=263.45 cfs 71.216 af

Subcatchment4S: SubBasin 4 Runoff Area=426.626 ac 0.00% Impervious Runoff Depth=4.28"
Flow Length=5,200' Slope=0.0422 '/' Tc=71.1 min CN=73 Runoff=640.21 cfs 152.243 af

Subcatchment5S: SubBasin 5 Runoff Area=754.731 ac 0.00% Impervious Runoff Depth=3.63"
Flow Length=13,607' Slope=0.0412 '/' Tc=182.7 min CN=67 Runoff=520.84 cfs 228.228 af

Subcatchment6S: SubBasin 6 Runoff Area=547.559 ac 0.00% Impervious Runoff Depth=4.95"
Flow Length=10,625' Slope=0.0513 '/' Tc=95.8 min CN=79 Runoff=789.98 cfs 225.953 af

Subcatchment7S: SubBasin 7 Runoff Area=867.188 ac 0.00% Impervious Runoff Depth=4.17"
Flow Length=12,289' Slope=0.0487 '/' Tc=135.4 min CN=72 Runoff=842.72 cfs 301.503 af

Subcatchment8S: SubBasin 8 Runoff Area=318.468 ac 0.00% Impervious Runoff Depth=4.06"
Flow Length=6,283' Slope=0.0400 '/' Tc=89.8 min CN=71 Runoff=392.35 cfs 107.815 af

Subcatchment9S: SubBasin 9 Runoff Area=593.693 ac 0.00% Impervious Runoff Depth=4.06"
Flow Length=9,201' Slope=0.0450 '/' Tc=114.8 min CN=71 Runoff=626.03 cfs 200.990 af

Reach 5R: Reach 5 Avg. Flow Depth=0.99' Max Vel=1.82 fps Inflow=95.92 cfs 197.807 af
L=5,162.0' S=0.0061 '/' Capacity=383,382.71 cfs Outflow=95.56 cfs 196.861 af

Reach 8R: Reach 8 Avg. Flow Depth=2.96' Max Vel=1.09 fps Inflow=626.03 cfs 200.990 af
L=3,310.0' S=0.0008 '/' Capacity=13,800.40 cfs Outflow=510.21 cfs 200.990 af

Pond 2B: Main/Storey Peak Elev=8.24' Inflow=754.90 cfs 1,310.762 af
Outflow=768.19 cfs 1,310.762 af

Pond 4B: Plummer/Middle Peak Elev=15.10' Storage=1,055.047 af Inflow=1,348.07 cfs 1,185.184 af
Outflow=713.16 cfs 1,171.383 af

Pond 5B: Rogers Peak Elev=17.33' Storage=196.235 af Inflow=1,354.78 cfs 726.575 af
Outflow=955.98 cfs 724.149 af

Pond 7B: Garden Peak Elev=41.47' Storage=1.525 af Inflow=842.72 cfs 301.503 af
Outflow=842.09 cfs 301.486 af

Pond 8B: Turkey Hill Peak Elev=16.65' Storage=4,786,463 cf Inflow=768.35 cfs 308.805 af
Outflow=264.29 cfs 308.792 af

Pond ARD: Artichoke River Dam Peak Elev=8.03' Storage=79.314 af Inflow=825.29 cfs 1,437.148 af
Outflow=807.52 cfs 1,435.950 af

Pond IHRD: Indian Hill Res. Dam Peak Elev=64.30' Storage=2,805.678 af Inflow=789.98 cfs 225.953 af
Outflow=95.92 cfs 197.807 af

Pond LARD: Lower Art. Res. Dam Peak Elev=11.05' Storage=301.972 af Inflow=768.68 cfs 1,319.732 af
Outflow=754.90 cfs 1,310.762 af

Pond UARD: Upper Art. Res. Dam Peak Elev=14.03' Storage=74.364 af Inflow=742.49 cfs 1,242.599 af
Outflow=742.26 cfs 1,241.379 af

Link HEC1: HECRAS 1 Inflow=333.48 cfs 126.386 af
Primary=333.48 cfs 126.386 af

Link HEC2: HECRAS 2 Inflow=439.72 cfs 78.353 af
Primary=439.72 cfs 78.353 af

Link HEC3: HECRAS 3 Inflow=263.45 cfs 71.216 af
Primary=263.45 cfs 71.216 af

Link HEC4: HECRAS 4
Primary=0.00 cfs 0.000 af

Total Runoff Area = 4,381.952 ac Runoff Volume = 1,492.686 af Average Runoff Depth = 4.09"
100.00% Pervious = 4,381.952 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 1S: SubBasin 1

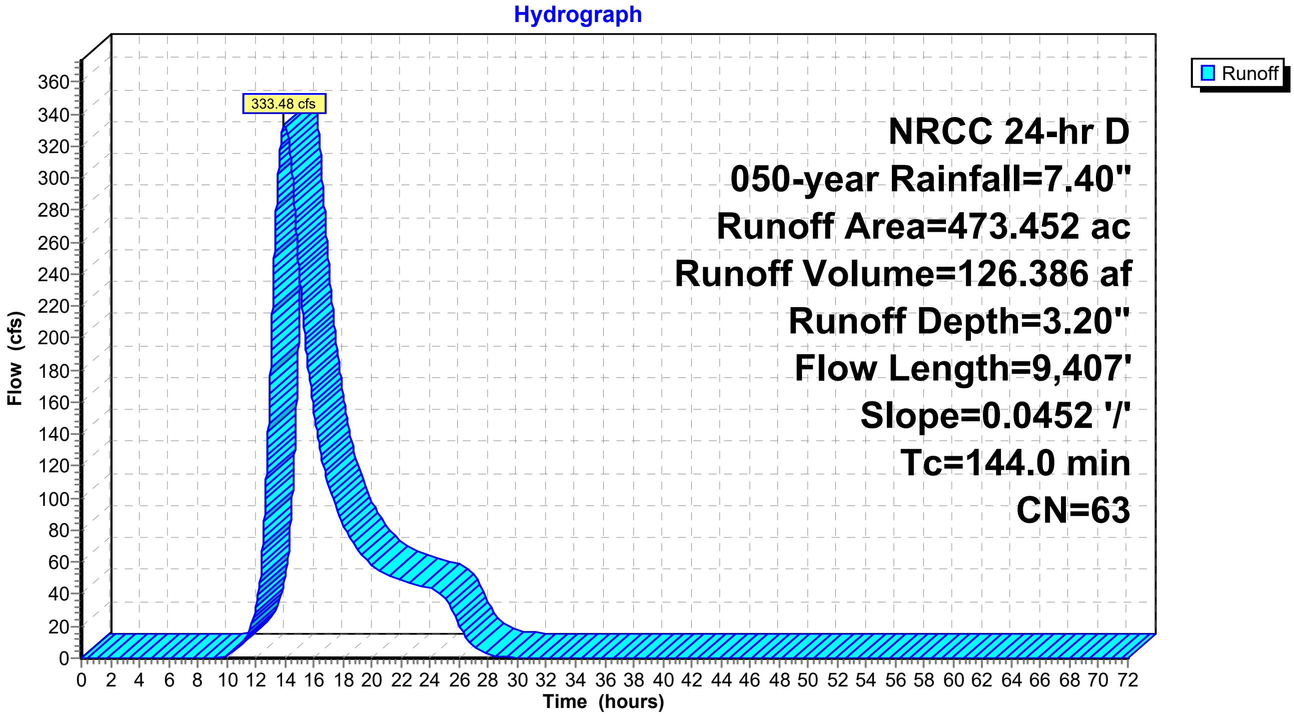
Runoff = 333.48 cfs @ 13.92 hrs, Volume= 126.386 af, Depth= 3.20"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 050-year Rainfall=7.40"

	Area (ac)	CN	Description
*	473.452	63	
	473.452		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
144.0	9,407	0.0452	1.09		**Lag/CN Method,**

Subcatchment 1S: SubBasin 1



Summary for Subcatchment 2S: SubBasin 2

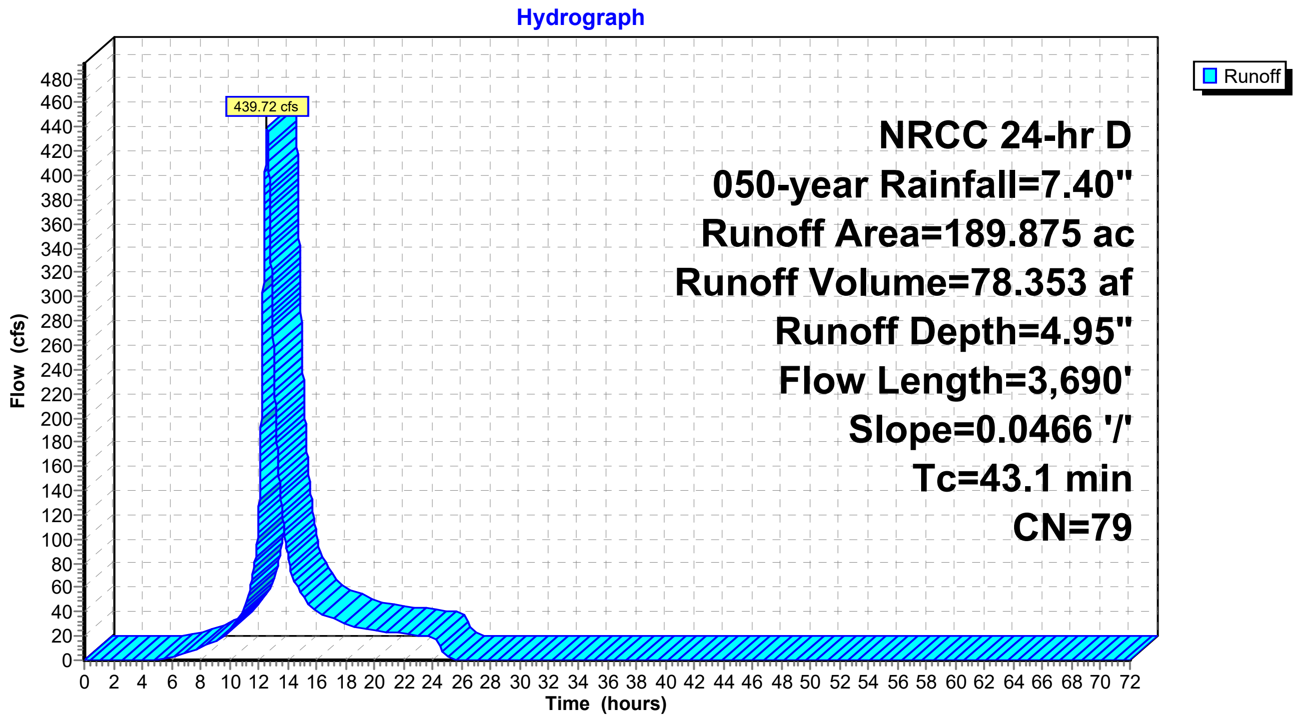
Runoff = 439.72 cfs @ 12.59 hrs, Volume= 78.353 af, Depth= 4.95"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 050-year Rainfall=7.40"

	Area (ac)	CN	Description
*	189.875	79	
	189.875		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
43.1	3,690	0.0466	1.43		**Lag/CN Method,**

Subcatchment 2S: SubBasin 2



Summary for Subcatchment 3S: SubBasin 3

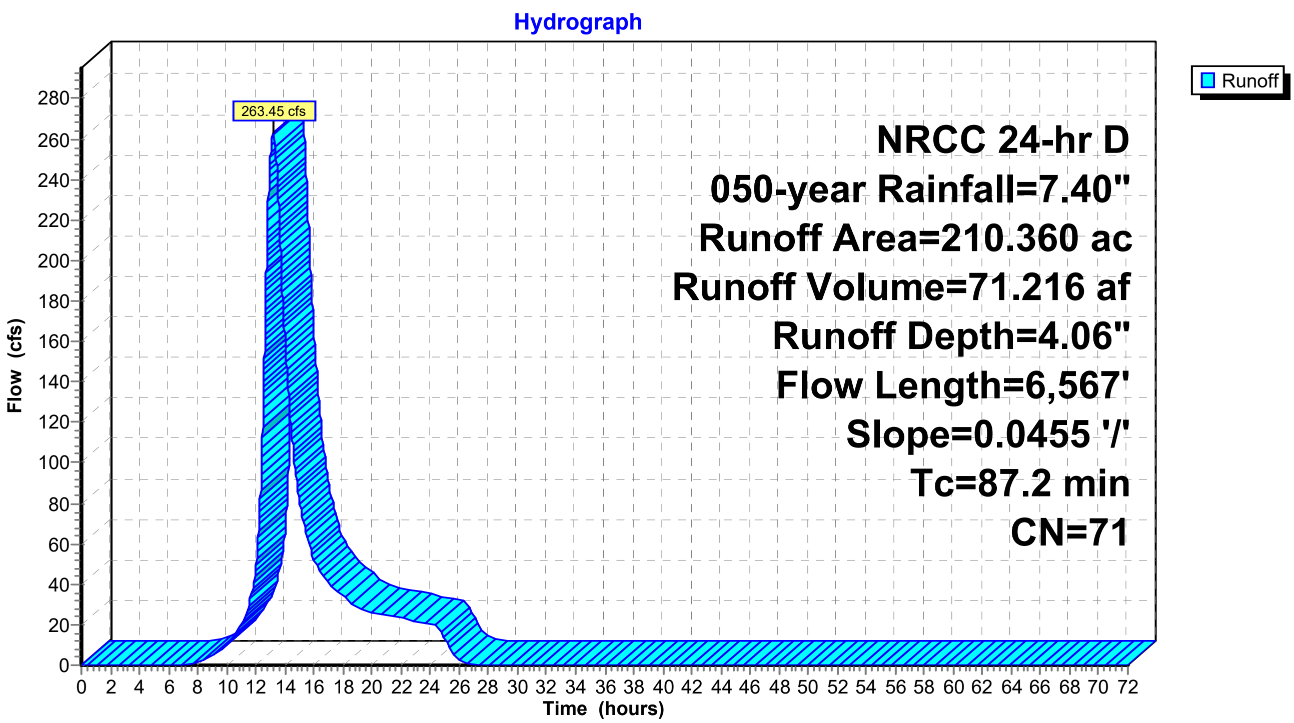
Runoff = 263.45 cfs @ 13.18 hrs, Volume= 71.216 af, Depth= 4.06"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 050-year Rainfall=7.40"

	Area (ac)	CN	Description
*	210.360	71	
	210.360		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
87.2	6,567	0.0455	1.26		**Lag/CN Method,**

Subcatchment 3S: SubBasin 3



Summary for Subcatchment 4S: SubBasin 4

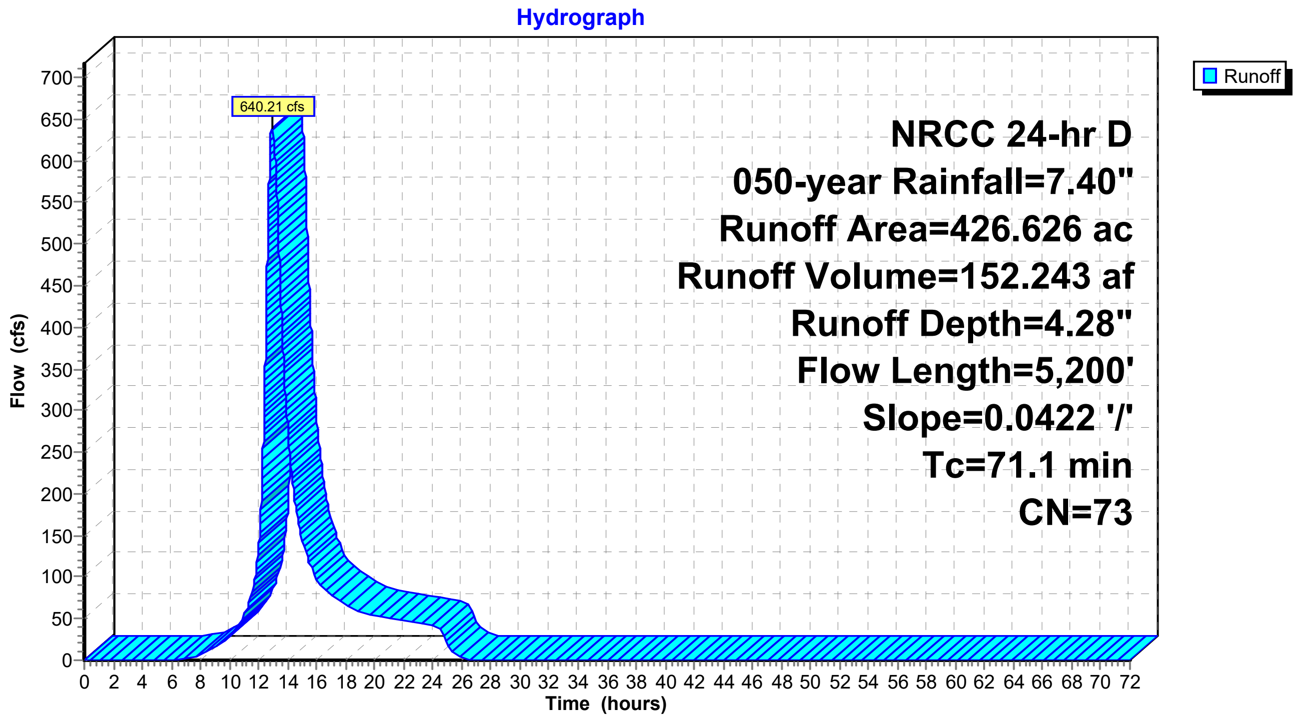
Runoff = 640.21 cfs @ 12.96 hrs, Volume= 152.243 af, Depth= 4.28"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 050-year Rainfall=7.40"

	Area (ac)	CN	Description
*	426.626	73	
	426.626		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
71.1	5,200	0.0422	1.22		**Lag/CN Method,**

Subcatchment 4S: SubBasin 4



Summary for Subcatchment 5S: SubBasin 5

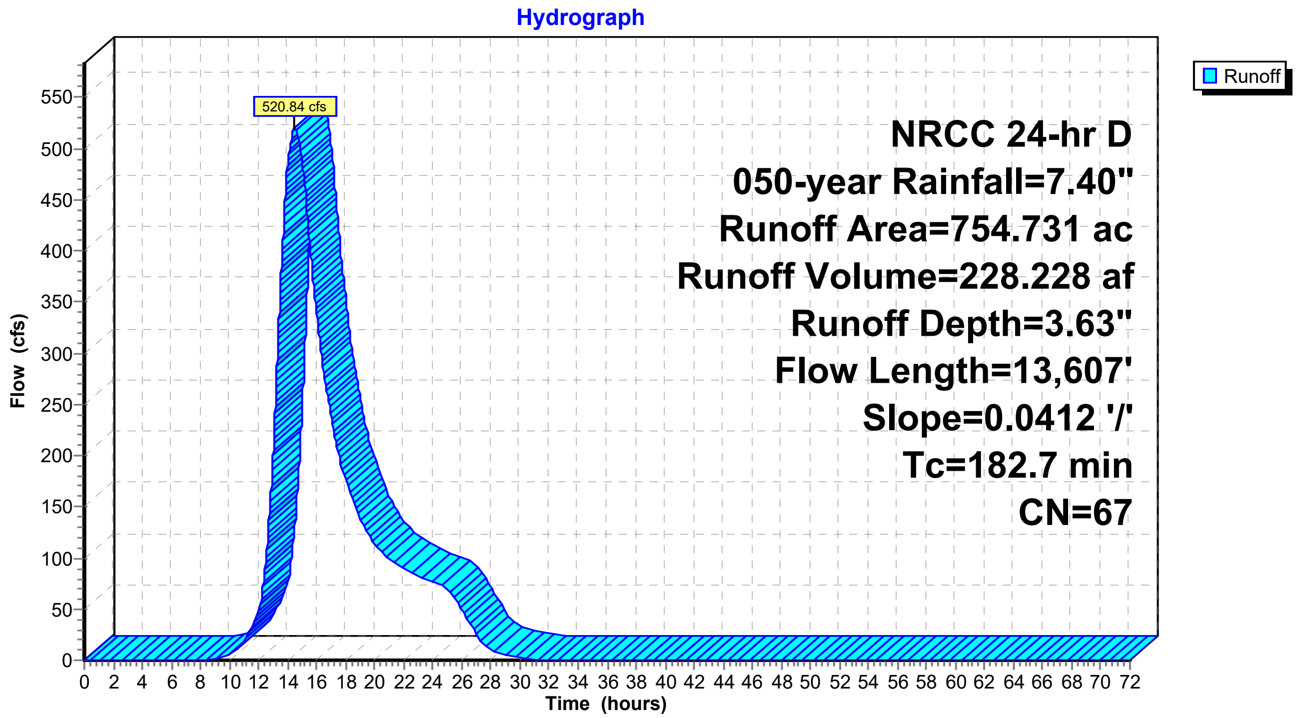
Runoff = 520.84 cfs @ 14.42 hrs, Volume= 228.228 af, Depth= 3.63"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 050-year Rainfall=7.40"

	Area (ac)	CN	Description
*	754.731	67	
	754.731		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
182.7	13,607	0.0412	1.24		**Lag/CN Method,**

Subcatchment 5S: SubBasin 5



Summary for Subcatchment 6S: SubBasin 6

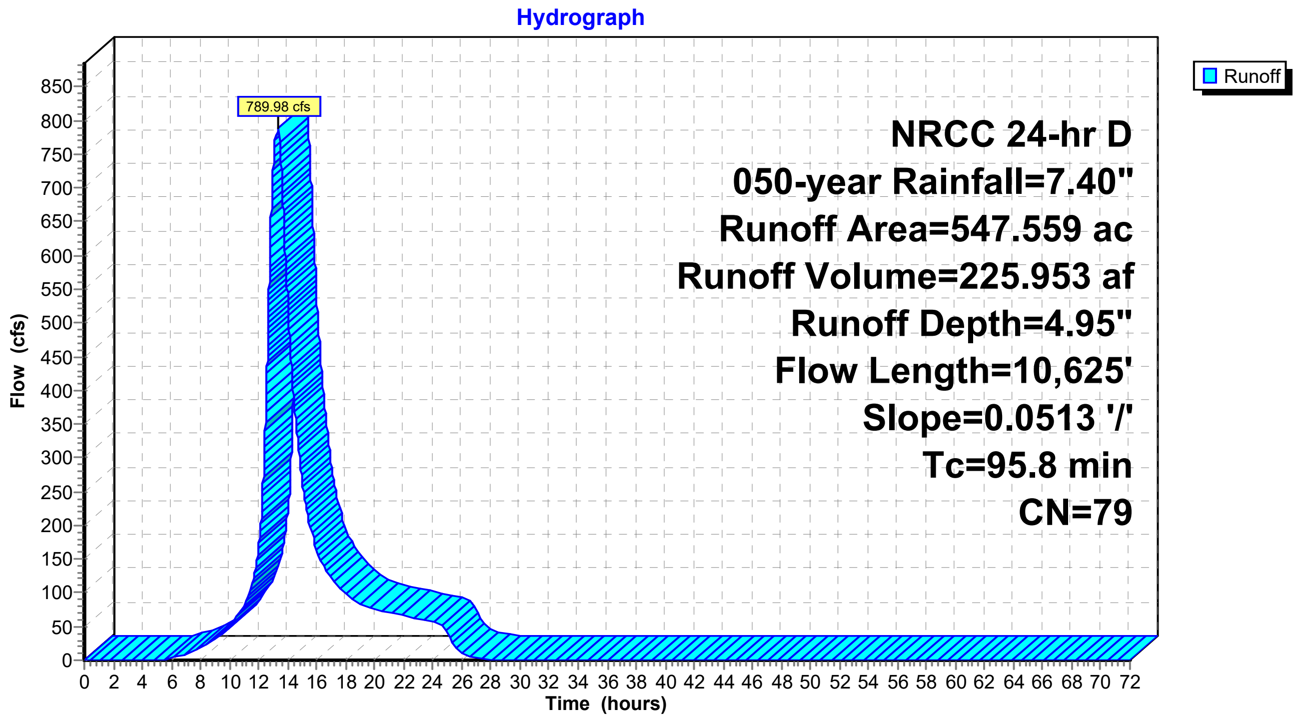
Runoff = 789.98 cfs @ 13.30 hrs, Volume= 225.953 af, Depth= 4.95"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 050-year Rainfall=7.40"

	Area (ac)	CN	Description
*	547.559	79	
	547.559		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
95.8	10,625	0.0513	1.85		**Lag/CN Method,**

Subcatchment 6S: SubBasin 6



Summary for Subcatchment 7S: SubBasin 7

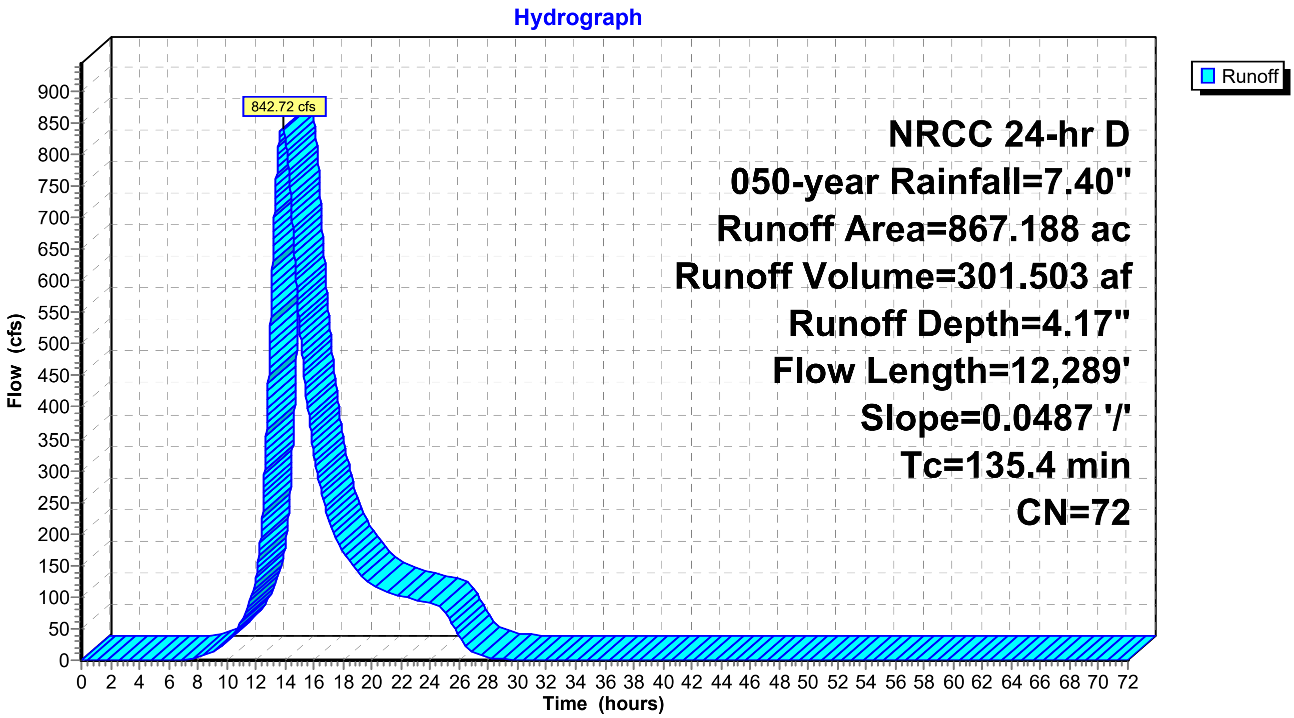
Runoff = 842.72 cfs @ 13.84 hrs, Volume= 301.503 af, Depth= 4.17"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 050-year Rainfall=7.40"

	Area (ac)	CN	Description
*	867.188	72	
	867.188		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
135.4	12,289	0.0487	1.51		**Lag/CN Method,**

Subcatchment 7S: SubBasin 7



Summary for Subcatchment 8S: SubBasin 8

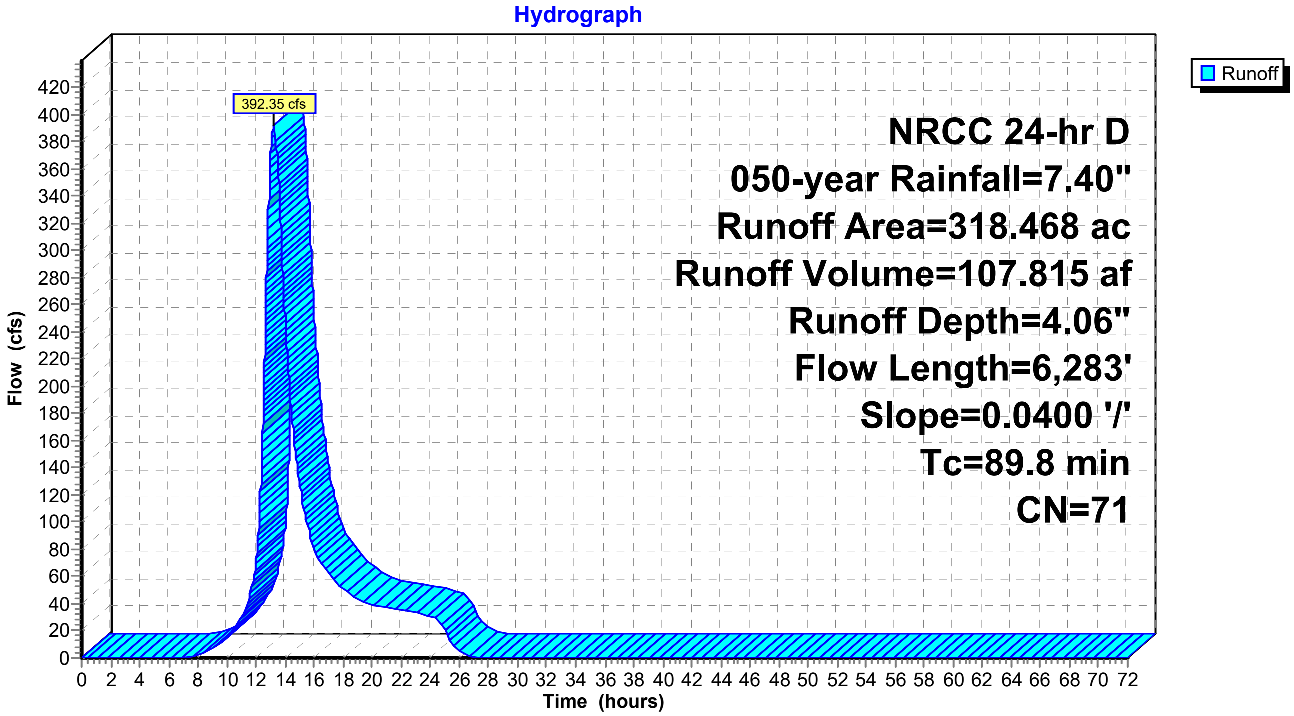
Runoff = 392.35 cfs @ 13.27 hrs, Volume= 107.815 af, Depth= 4.06"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 050-year Rainfall=7.40"

	Area (ac)	CN	Description
*	318.468	71	
	318.468		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
89.8	6,283	0.0400	1.17		**Lag/CN Method,**

Subcatchment 8S: SubBasin 8



Summary for Subcatchment 9S: SubBasin 9

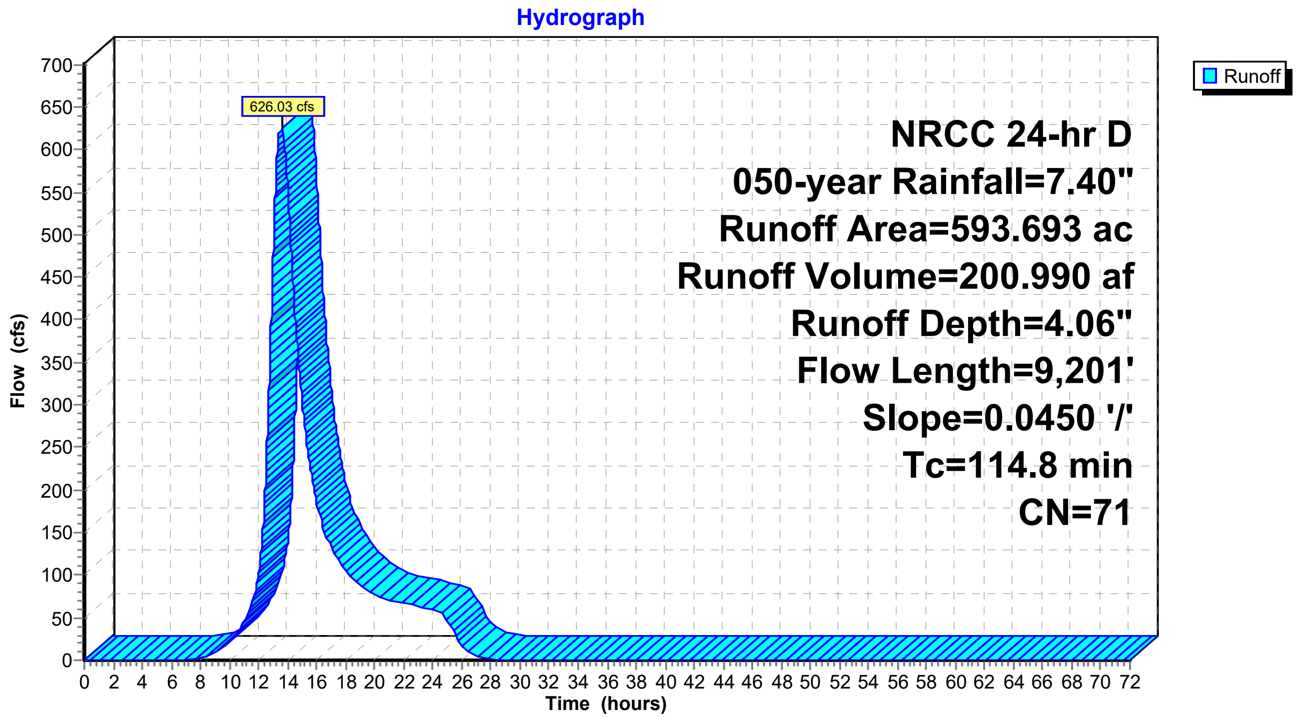
Runoff = 626.03 cfs @ 13.64 hrs, Volume= 200.990 af, Depth= 4.06"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
NRCC 24-hr D 050-year Rainfall=7.40"

	Area (ac)	CN	Description
*	593.693	71	
	593.693		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
114.8	9,201	0.0450	1.34		**Lag/CN Method,**

Subcatchment 9S: SubBasin 9



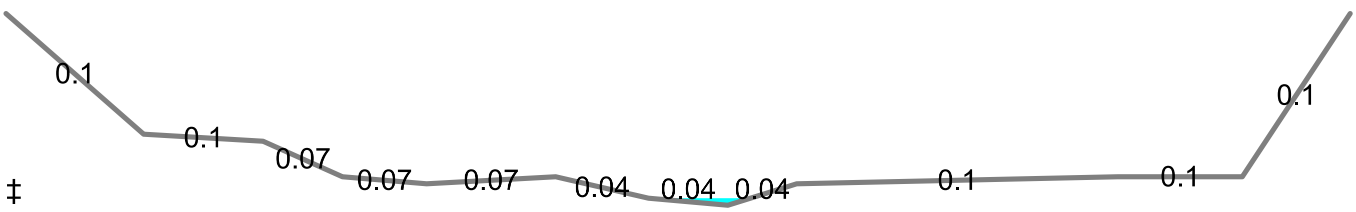
Summary for Reach 5R: Reach 5

Inflow Area = 547.559 ac, 0.00% Impervious, Inflow Depth > 4.34" for 050-year event
Inflow = 95.92 cfs @ 18.22 hrs, Volume= 197.807 af
Outflow = 95.56 cfs @ 18.96 hrs, Volume= 196.861 af, Atten= 0%, Lag= 43.9 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 2
Max. Velocity= 1.82 fps, Min. Travel Time= 47.2 min
Avg. Velocity = 1.34 fps, Avg. Travel Time= 64.0 min

Peak Storage= 270,449 cf @ 18.96 hrs
Average Depth at Peak Storage= 0.99'
Bank-Full Depth= 27.00' Flow Area= 28,951.0 sf, Capacity= 383,382.71 cfs

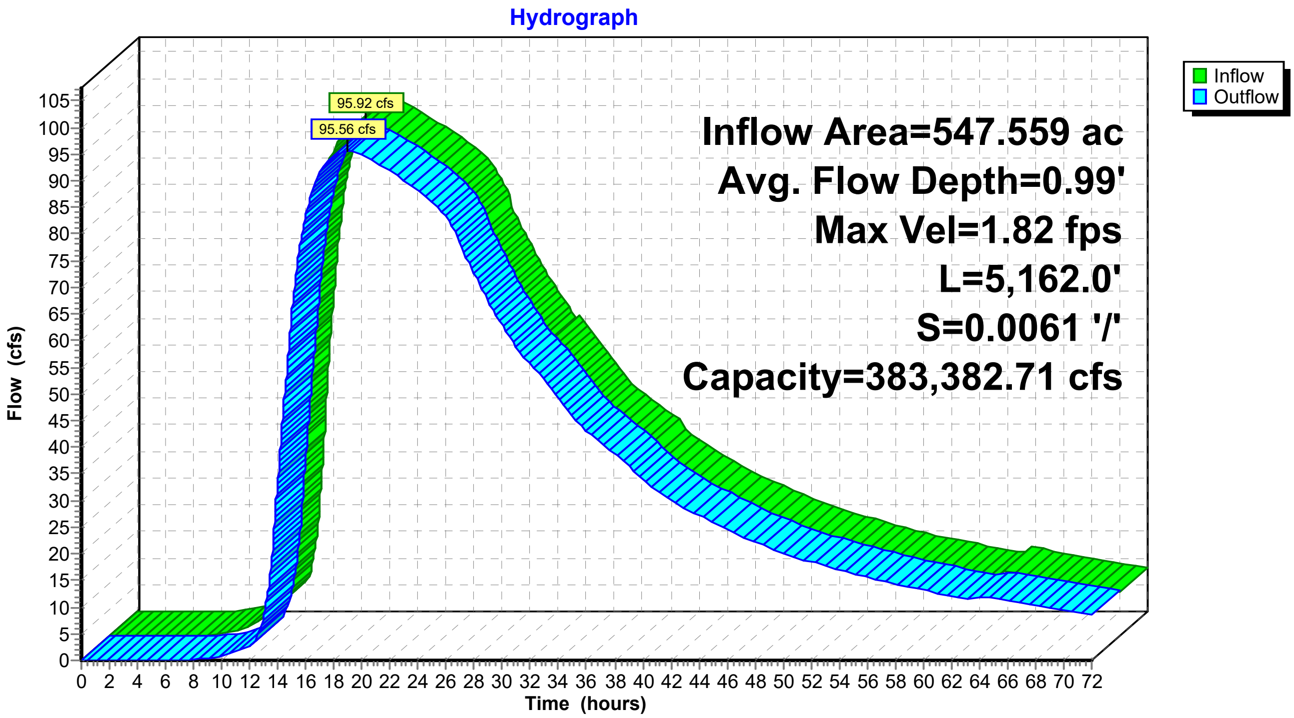
Custom cross-section, Length= 5,162.0' Slope= 0.0061 '/' (105 Elevation Intervals)
Flow calculated by Manning's Subdivision method
Inlet Invert= 38.70', Outlet Invert= 7.00'



Offset (feet)	Elevation (feet)	Chan.Depth (feet)	n	Description
0.00	24.00	0.00		
144.00	7.00	17.00	0.100	Heavy timber, flow below branches
269.00	6.00	18.00	0.100	
352.00	1.00	23.00	0.070	Medium-dense brush, winter
440.00	0.00	24.00	0.070	
575.00	1.00	23.00	0.070	
672.00	-2.00	26.00	0.040	Winding stream, pools & shoals
755.00	-3.00	27.00	0.040	
827.00	0.00	24.00	0.040	
1,163.00	1.00	23.00	0.100	Heavy timber, flow below branches
1,293.00	1.00	23.00	0.100	
1,406.00	24.00	0.00	0.100	

Depth (feet)	End Area (sq-ft)	Perim. (feet)	Storage (cubic-feet)	Discharge (cfs)
0.00	0.0	0.0	0	0.00
1.00	53.5	107.0	276,167	98.10
3.00	380.2	219.8	1,962,420	1,594.88
4.00	895.5	941.1	4,622,571	3,469.18
9.00	5,869.4	1,049.3	30,297,910	36,453.77
10.00	6,982.9	1,179.4	36,045,909	46,882.22
27.00	28,951.0	1,409.6	149,445,062	383,382.71

Reach 5R: Reach 5



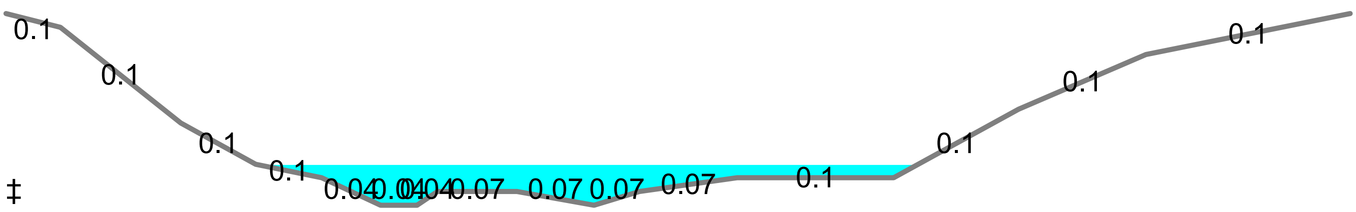
Summary for Reach 8R: Reach 8

Inflow Area = 593.693 ac, 0.00% Impervious, Inflow Depth = 4.06" for 050-year event
Inflow = 626.03 cfs @ 13.64 hrs, Volume= 200.990 af
Outflow = 510.21 cfs @ 14.17 hrs, Volume= 200.990 af, Atten= 19%, Lag= 31.7 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 2
Max. Velocity= 1.09 fps, Min. Travel Time= 50.6 min
Avg. Velocity = 0.39 fps, Avg. Travel Time= 141.4 min

Peak Storage= 1,548,891 cf @ 14.17 hrs
Average Depth at Peak Storage= 2.96'
Bank-Full Depth= 14.00' Flow Area= 5,068.0 sf, Capacity= 13,800.40 cfs

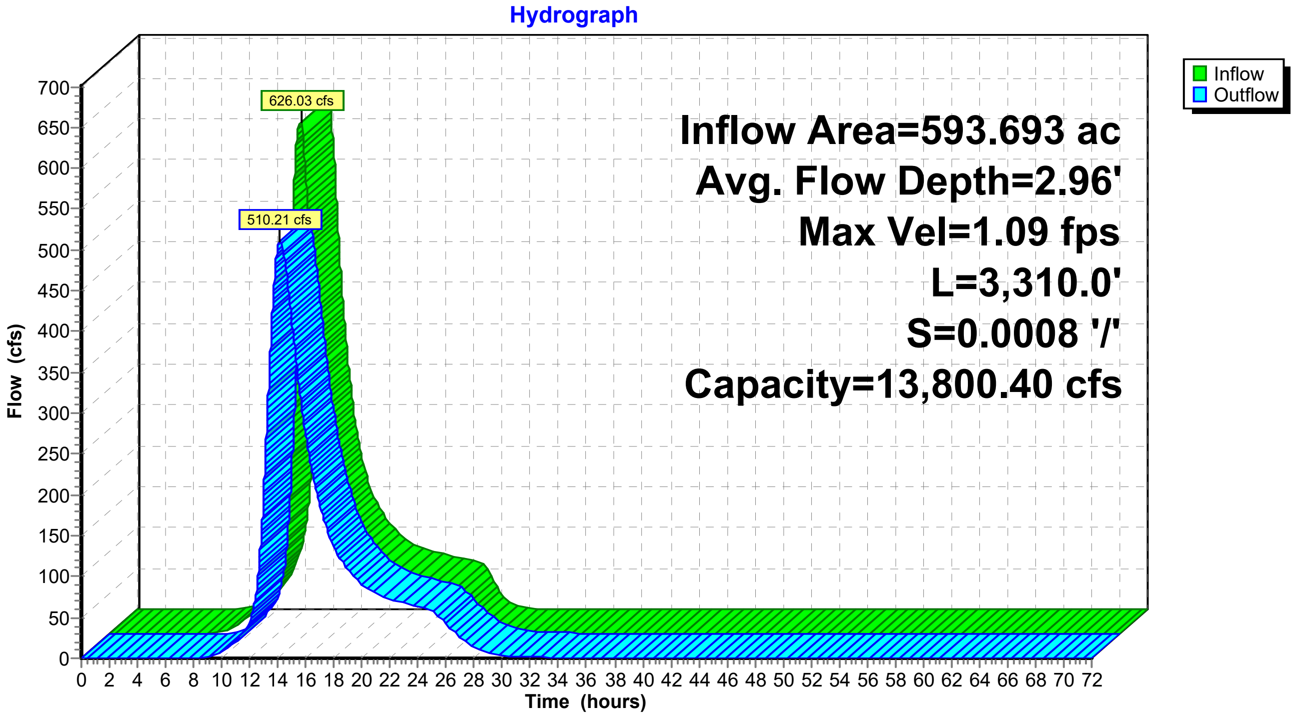
Custom cross-section, Length= 3,310.0' Slope= 0.0008 '/' (106 Elevation Intervals)
Flow calculated by Manning's Subdivision method
Inlet Invert= 16.23', Outlet Invert= 13.53'



Offset (feet)	Elevation (feet)	Chan.Depth (feet)	n	Description
0.00	31.00	0.00		
24.00	30.00	1.00	0.100	Heavy timber, flow below branches
77.00	23.00	8.00	0.100	
110.00	20.00	11.00	0.100	
139.00	19.00	12.00	0.100	
165.00	17.00	14.00	0.040	Winding stream, pools & shoals
181.00	17.00	14.00	0.040	
190.00	18.00	13.00	0.040	
225.00	18.00	13.00	0.070	Sluggish weedy reaches w/pools
259.00	17.00	14.00	0.070	
279.00	18.00	13.00	0.070	
322.00	19.00	12.00	0.070	
391.00	19.00	12.00	0.100	Heavy timber, flow below branches
446.00	24.00	7.00	0.100	
502.00	28.00	3.00	0.100	
592.00	31.00	0.00	0.100	

Depth (feet)	End Area (sq-ft)	Perim. (feet)	Storage (cubic-feet)	Discharge (cfs)
0.00	0.0	16.0	0	0.00
1.00	54.0	127.1	178,740	30.16
2.00	209.0	252.2	691,790	180.51
3.00	481.0	292.2	1,592,110	529.63
6.00	1,456.0	358.5	4,819,360	2,536.86
7.00	1,823.3	377.2	6,035,076	3,497.74
11.00	3,502.1	463.9	11,592,093	8,691.29
13.00	4,503.0	539.2	14,904,930	11,992.10
14.00	5,068.0	593.2	16,775,080	13,800.40

Reach 8R: Reach 8



Summary for Pond 2B: Main/Storey

Main/Storey

[57] Hint: Peaked at 8.24' (Flood elevation advised)
[90] Warning: Qout>Qin may require smaller dt or Finer Routing
[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=3078)

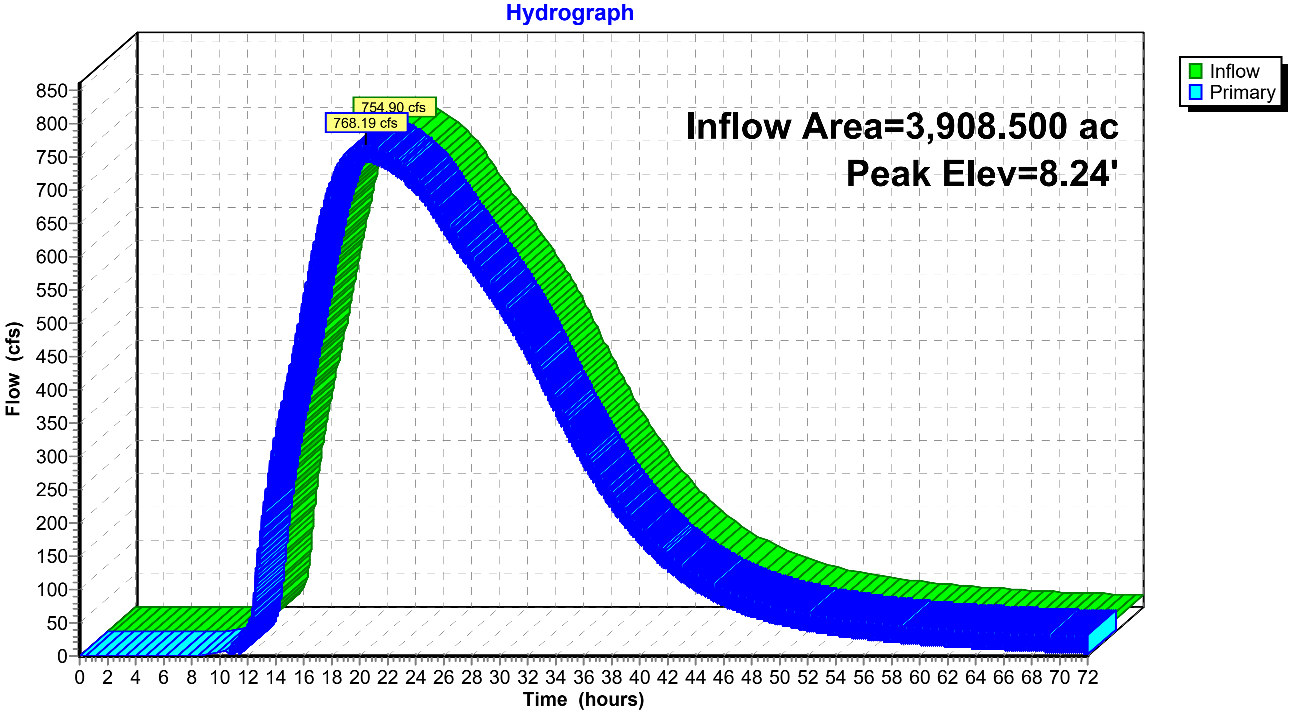
Inflow Area = 3,908.500 ac, 0.00% Impervious, Inflow Depth > 4.02" for 050-year event
Inflow = 754.90 cfs @ 20.48 hrs, Volume= 1,310.762 af
Outflow = 768.19 cfs @ 20.48 hrs, Volume= 1,310.762 af, Atten= 0%, Lag= 0.0 min
Primary = 768.19 cfs @ 20.48 hrs, Volume= 1,310.762 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 2
Peak Elev= 8.24' @ 20.76 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	-0.50'	**Bridge Opening, Cv= 2.62 (C= 3.28)** Head (feet) 0.00 16.50 Width (feet) 25.00 82.10
#2	Primary	20.50'	**630.0' long x 44.0' breadth Top of Road** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=768.19 cfs @ 20.48 hrs HW=8.24' TW=8.03' (Dynamic Tailwater)
├─**1=Bridge Opening** (Weir Controls 768.19 cfs @ 2.19 fps)
└─**2=Top of Road** (Controls 0.00 cfs)

Pond 2B: Main/Storey



Summary for Pond 4B: Plummer/Middle

[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=39)
[80] Warning: Exceeded Pond 8B by 1.80' @ 6.39 hrs (46.62 cfs 65.782 af)

Inflow Area = 3,508.265 ac, 0.00% Impervious, Inflow Depth > 4.05" for 050-year event
Inflow = 1,348.07 cfs @ 15.24 hrs, Volume= 1,185.184 af
Outflow = 713.16 cfs @ 19.07 hrs, Volume= 1,171.383 af, Atten= 47%, Lag= 229.9 min
Primary = 713.16 cfs @ 19.07 hrs, Volume= 1,171.383 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 2
Starting Elev= 12.40' Surf.Area= 0.000 ac Storage= 725.776 af
Peak Elev= 15.10' @ 19.02 hrs Surf.Area= 0.000 ac Storage= 1,055.047 af (329.271 af above start)

Plug-Flow detention time= 1,349.1 min calculated for 445.607 af (38% of inflow)
Center-of-Mass det. time= 317.0 min (1,619.3 - 1,302.3)

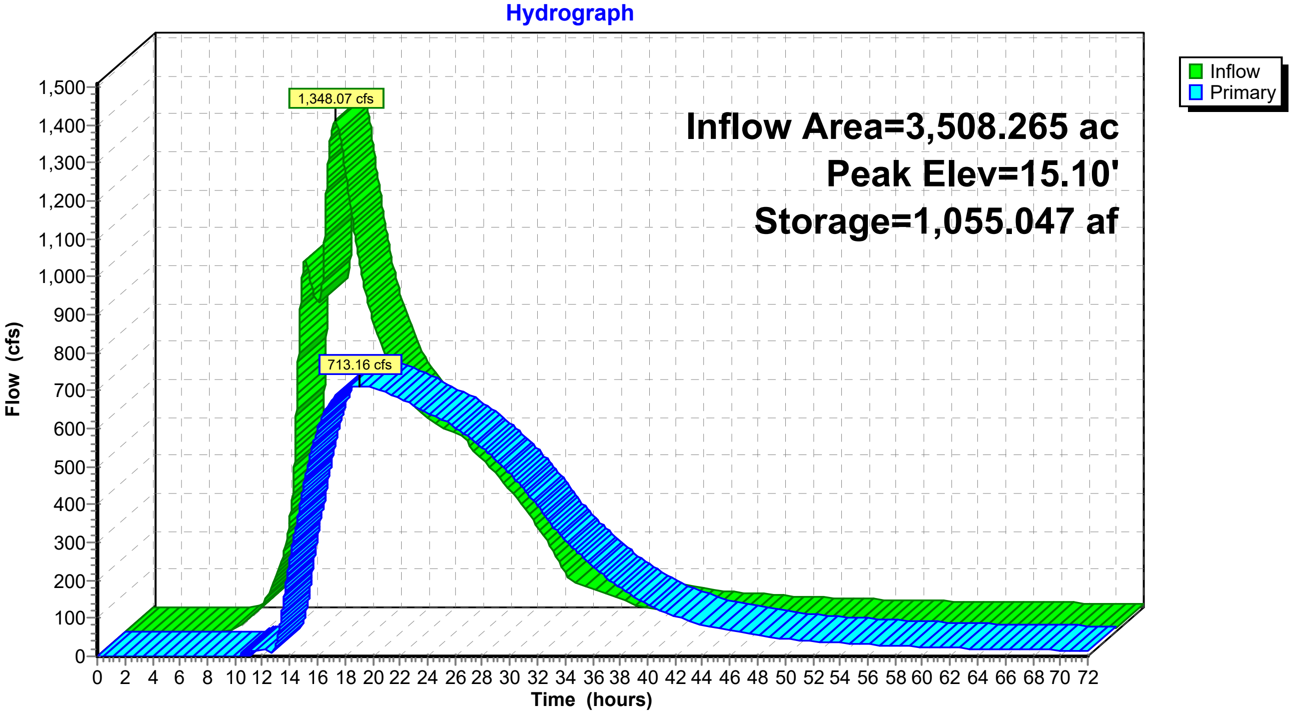
Volume	Invert	Avail.Storage	Storage Description
#1	1.06'	3,614.312 af	**Custom Stage Data**Listed below

Elevation (feet)	Cum.Store (acre-feet)
1.06	0.000
3.00	0.140
3.33	0.640
3.62	1.390
4.63	20.370
6.00	95.090
8.34	291.289
12.52	738.618
15.04	1,047.508
18.70	1,542.126
21.10	1,899.206
24.72	2,482.604
27.18	2,908.563
29.66	3,360.872
31.00	3,614.312

Device	Routing	Invert	Outlet Devices
#1	Primary	17.90'	**330.0' long x 18.0' breadth Top of Road** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#2	Primary	2.40'	**168.0" W x 151.2" H, R=120.0" Arch Culvert** L= 18.0' Box, 0° wingwalls, square crown edge, Ke= 0.700 Inlet / Outlet Invert= 2.40' / 2.40' S= 0.0000 '/' Cc= 0.900 n= 0.025 Rubble masonry, cemented, Flow Area= 163.93 sf

Primary OutFlow Max=713.34 cfs @ 19.07 hrs HW=15.10' TW=14.03' (Dynamic Tailwater)
1=Top of Road (Controls 0.00 cfs)
2=Culvert (Inlet Controls 713.34 cfs @ 4.35 fps)

Pond 4B: Plummer/Middle



Summary for Pond 5B: Rogers

[62] Hint: Exceeded Reach 5R OUTLET depth by 9.44' @ 15.22 hrs

Inflow Area = 2,169.478 ac, 0.00% Impervious, Inflow Depth > 4.02" for 050-year event
Inflow = 1,354.78 cfs @ 14.03 hrs, Volume= 726.575 af
Outflow = 955.98 cfs @ 15.31 hrs, Volume= 724.149 af, Atten= 29%, Lag= 76.5 min
Primary = 955.98 cfs @ 15.31 hrs, Volume= 724.149 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 2
Starting Elev= 12.40' Surf.Area= 0.000 ac Storage= 41.030 af
Peak Elev= 17.33' @ 15.36 hrs Surf.Area= 0.000 ac Storage= 196.235 af (155.205 af above start)

Plug-Flow detention time= 350.7 min calculated for 683.119 af (94% of inflow)
Center-of-Mass det. time= 186.6 min (1,420.8 - 1,234.2)

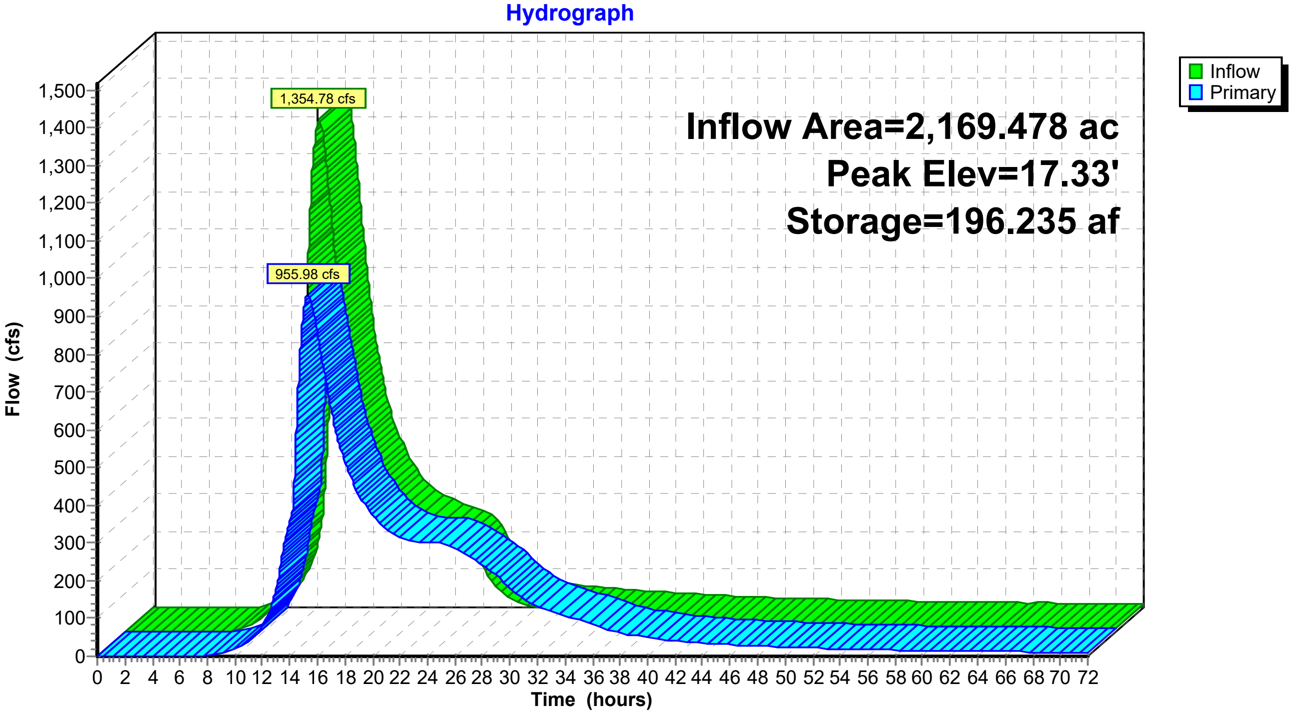
Volume	Invert	Avail.Storage	Storage Description
#1	7.00'	1,165.407 af	**Custom Stage Data**Listed below

Elevation (feet)	Cum.Store (acre-feet)
7.00	0.000
7.51	0.230
8.00	0.650
8.66	2.420
9.24	5.010
10.84	19.120
11.98	33.260
13.50	61.380
15.04	104.930
16.42	154.450
18.12	232.609
20.49	372.739
26.05	766.568
31.03	1,165.407

Device	Routing	Invert	Outlet Devices
#1	Primary	16.50'	**275.0' long x 30.0' breadth Top of Road** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#2	Primary	8.00'	**102.0" W x 78.0" H Box Culvert** L= 25.0' Box, 0° wingwalls, square crown edge, Ke= 0.700 Inlet / Outlet Invert= 8.00' / 8.00' S= 0.0000 '/' Cc= 0.900 n= 0.025 Rubble masonry, cemented, Flow Area= 55.25 sf

Primary OutFlow Max=955.97 cfs @ 15.31 hrs HW=17.33' TW=14.28' (Dynamic Tailwater)
↑—**1=Top of Road** (Weir Controls 546.62 cfs @ 2.40 fps)
└—**2=Culvert** (Inlet Controls 409.34 cfs @ 7.41 fps)

Pond 5B: Rogers



Summary for Pond 7B: Garden

Inflow Area = 867.188 ac, 0.00% Impervious, Inflow Depth = 4.17" for 050-year event
Inflow = 842.72 cfs @ 13.84 hrs, Volume= 301.503 af
Outflow = 842.09 cfs @ 13.86 hrs, Volume= 301.486 af, Atten= 0%, Lag= 1.0 min
Primary = 842.09 cfs @ 13.86 hrs, Volume= 301.486 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 2
Peak Elev= 41.47' @ 13.86 hrs Surf.Area= 0.000 ac Storage= 1.525 af

Plug-Flow detention time= 0.9 min calculated for 301.444 af (100% of inflow)
Center-of-Mass det. time= 0.9 min (967.4 - 966.5)

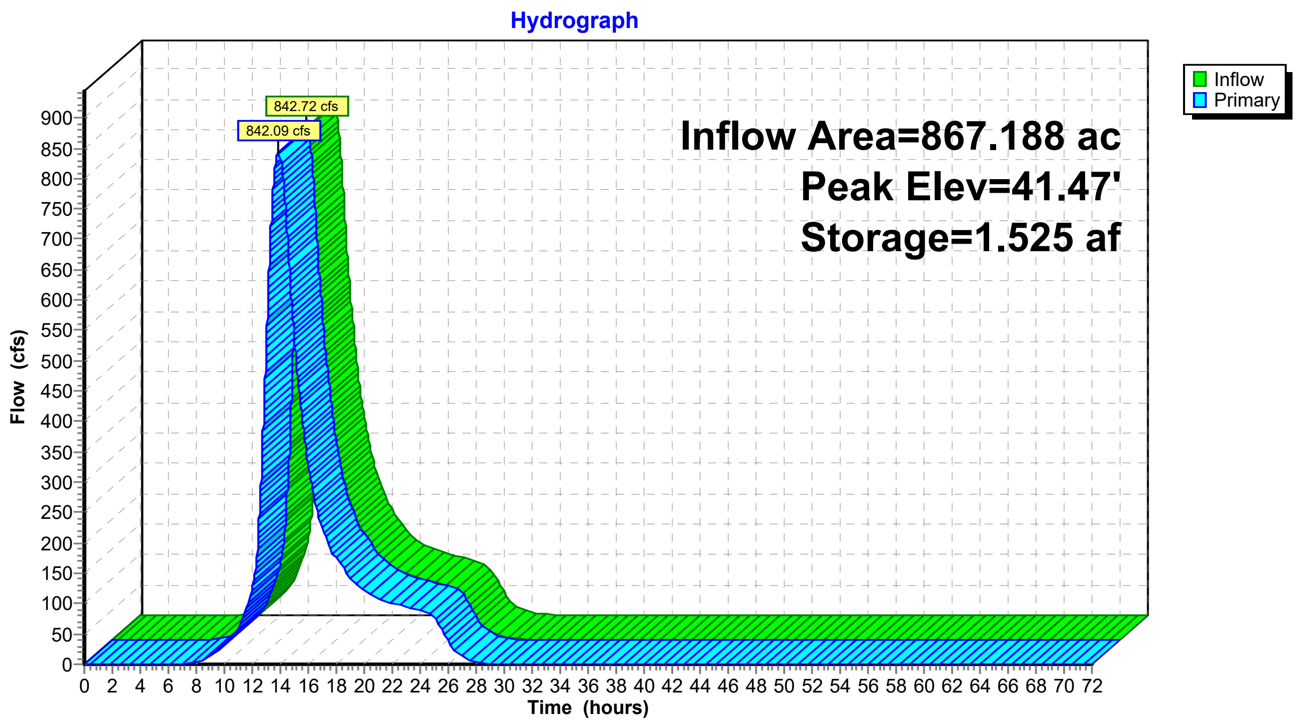
Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	10.300 af	**Custom Stage Data**Listed below

Elevation (feet)	Cum.Store (acre-feet)
0.00	0.000
33.82	0.020
35.29	0.050
36.55	0.100
37.41	0.160
38.19	0.250
38.73	0.330
39.29	0.460
39.86	0.630
40.41	0.850
40.89	1.110
41.33	1.410
41.72	1.740
42.08	2.120
42.41	2.550
42.74	3.070
43.10	3.730
43.42	4.460
43.73	5.280
44.03	6.220
44.37	7.460
44.71	8.840
45.02	10.300

Device	Routing	Invert	Outlet Devices
#1	Primary	38.40'	**45.0' long x 30.0' breadth Top of the Road** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#2	Primary	27.80'	**48.0" Round Culvert** L= 30.0' Box, 10-30° wingwalls, square crown, Ke= 0.500 Inlet / Outlet Invert= 27.80' / 27.70' S= 0.0033 '/' Cc= 0.900 n= 0.012 Concrete pipe, finished, Flow Area= 12.57 sf

Primary OutFlow Max=842.07 cfs @ 13.86 hrs HW=41.47' TW=15.72' (Dynamic Tailwater)
↑**1=Top of the Road** (Weir Controls 635.40 cfs @ 4.61 fps)
└**2=Culvert** (Inlet Controls 206.67 cfs @ 16.45 fps)

Pond 7B: Garden



Summary for Pond 8B: Turkey Hill

[62] Hint: Exceeded Reach 8R OUTLET depth by 1.39' @ 19.43 hrs

Inflow Area = 912.161 ac, 0.00% Impervious, Inflow Depth = 4.06" for 050-year event
Inflow = 768.35 cfs @ 13.71 hrs, Volume= 308.805 af
Outflow = 264.29 cfs @ 15.25 hrs, Volume= 308.792 af, Atten= 66%, Lag= 92.2 min
Primary = 264.29 cfs @ 15.25 hrs, Volume= 308.792 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 2
Peak Elev= 16.65' @ 17.03 hrs Surf.Area= 0 sf Storage= 4,786,463 cf

Plug-Flow detention time= 236.1 min calculated for 308.749 af (100% of inflow)
Center-of-Mass det. time= 236.0 min (1,220.7 - 984.7)

Volume	Invert	Avail.Storage	Storage Description
#1	10.60'	33,554,191 cf	**Custom Stage Data**Listed below

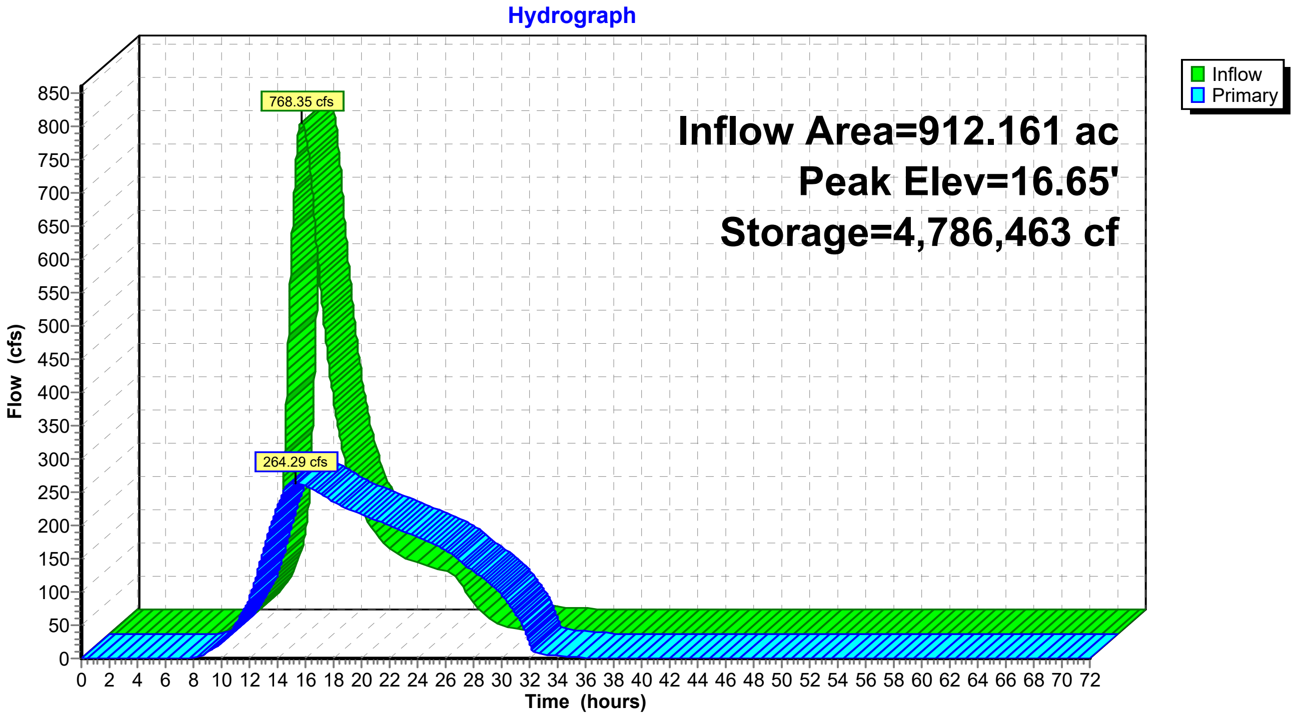
Elevation (feet)	Cum.Store (cubic-feet)
10.60	0
13.11	871
13.22	2,614
13.32	5,227
13.41	9,583
13.49	15,246
13.65	32,670
13.84	63,162
13.97	94,089
14.10	138,956
14.22	198,633
14.35	278,348
14.47	371,130
14.71	607,225
14.92	892,978
15.16	1,303,748
15.47	1,924,912
15.80	2,642,344
16.21	3,652,062
16.70	4,911,379
17.78	7,881,728
19.05	11,572,123
20.39	15,622,758
21.91	20,402,586
23.88	26,764,509
25.95	33,554,191

Device	Routing	Invert	Outlet Devices
#1	Primary	18.20'	**50.0' long x 25.0' breadth Top of Road** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

#2	Primary	10.70'	**102.0" W x 66.0" H Box Culvert** L= 25.0' Box, 0° wingwalls, square crown edge, Ke= 0.700 Inlet / Outlet Invert= 10.70' / 10.60' S= 0.0040 '/' Cc= 0.900 n= 0.013 Concrete, trowel finish, Flow Area= 46.75 sf

Primary OutFlow Max=264.29 cfs @ 15.25 hrs HW=16.43' TW=14.25' (Dynamic Tailwater)
↑—**1=Top of Road** (Controls 0.00 cfs)
└—**2=Culvert** (Inlet Controls 264.29 cfs @ 5.65 fps)

Pond 8B: Turkey Hill



Summary for Pond ARD: Artichoke River Dam

[80] Warning: Exceeded Pond 2B by 4.69' @ 0.00 hrs (1,128.38 cfs 192.643 af)

Inflow Area = 4,381.952 ac, 0.00% Impervious, Inflow Depth > 3.94" for 050-year event
Inflow = 825.29 cfs @ 19.70 hrs, Volume= 1,437.148 af
Outflow = 807.52 cfs @ 20.81 hrs, Volume= 1,435.950 af, Atten= 2%, Lag= 66.4 min
Primary = 807.52 cfs @ 20.81 hrs, Volume= 1,435.950 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 2
Starting Elev= 4.40' Surf.Area= 0.000 ac Storage= 17.307 af
Peak Elev= 8.03' @ 20.81 hrs Surf.Area= 0.000 ac Storage= 79.314 af (62.007 af above start)

Plug-Flow detention time= 94.9 min calculated for 1,418.643 af (99% of inflow)
Center-of-Mass det. time= 52.8 min (1,653.8 - 1,601.0)

Volume	Invert	Avail.Storage	Storage Description
#1	-0.51'	2,226.935 af	**Custom Stage Data**Listed below

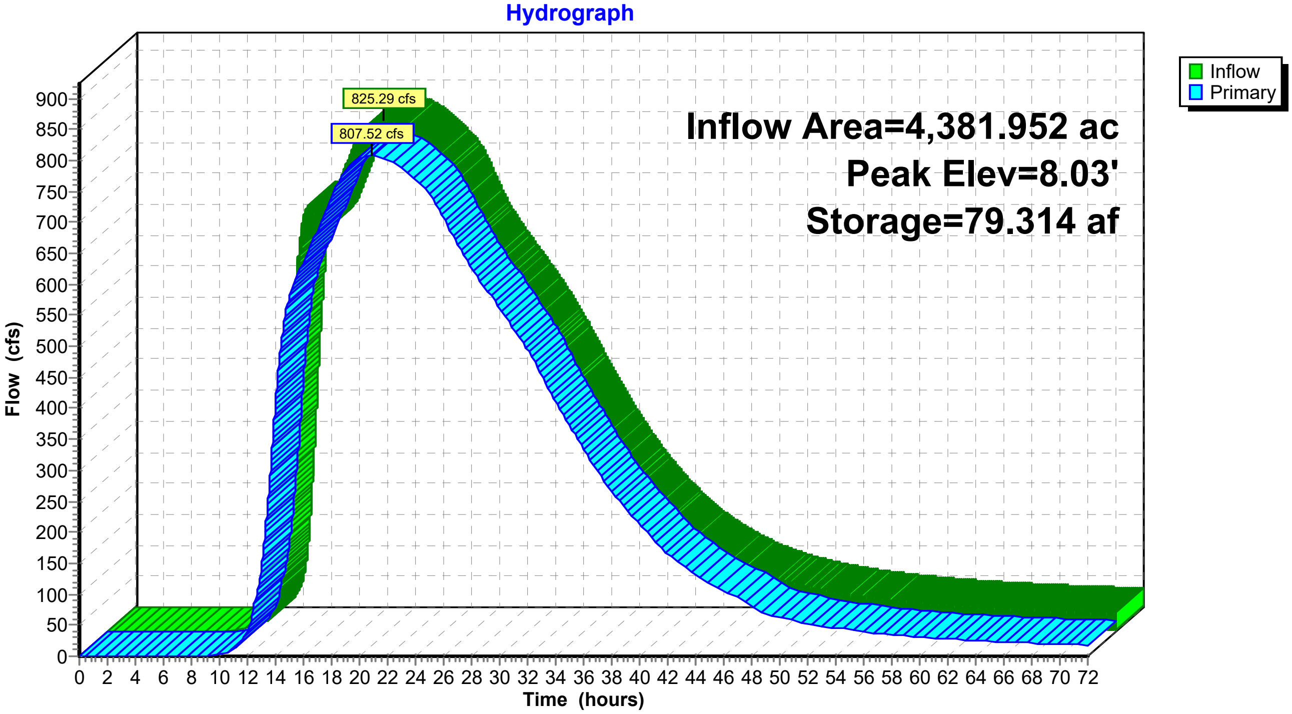
Elevation (feet)	Cum.Store (acre-feet)
-0.51	0.000
5.34	20.620
6.04	32.770
7.14	55.410
8.11	81.340
9.10	117.040
11.17	211.100
14.07	368.899
17.86	607.589
21.68	880.678
24.35	1,089.067
28.70	1,455.627
31.62	1,718.426
34.49	1,990.465
35.87	2,127.365
36.85	2,226.935

Device	Routing	Invert	Outlet Devices
#1	Primary	4.40'	**36.0' long x 3.0' breadth Primary Spillway** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	6.20'	**9.0' long x 3.0' breadth Training Walls** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#3	Primary	11.00'	**40.0' long x 12.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60

Coef. (English) 2.57 2.62 2.70 2.67 2.66 2.67 2.66 2.64

Primary OutFlow Max=807.52 cfs @ 20.81 hrs HW=8.03' (Free Discharge)
1=Primary Spillway (Weir Controls 747.45 cfs @ 5.71 fps)
2=Training Walls (Weir Controls 60.07 cfs @ 3.64 fps)
3=Broad-Crested Rectangular Weir (Controls 0.00 cfs)

Pond ARD: Artichoke River Dam



Summary for Pond IHRD: Indian Hill Res. Dam

[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=2)

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Inflow Area =      547.559 ac,   0.00% Impervious,  Inflow Depth =   4.95"    for  050-year event
Inflow      =      789.98 cfs @   13.30 hrs,  Volume=        225.953 af
Outflow     =       95.92 cfs @   18.22 hrs,  Volume=        197.807 af,  Atten= 88%,  Lag= 295.5 min
Primary     =       95.92 cfs @   18.22 hrs,  Volume=        197.807 af
```

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 2
Starting Elev= 63.20' Surf.Area= 0.000 ac Storage= 2,656.421 af
Peak Elev= 64.30' @ 18.22 hrs Surf.Area= 0.000 ac Storage= 2,805.678 af (149.257 af above start)

Plug-Flow detention time= (not calculated: initial storage exceeds outflow)
Center-of-Mass det. time= 934.4 min (1,843.6 - 909.2)

Volume	Invert	Avail.Storage	Storage Description
#1	37.00'	6,036.096 af	**Custom Stage Data**Listed below

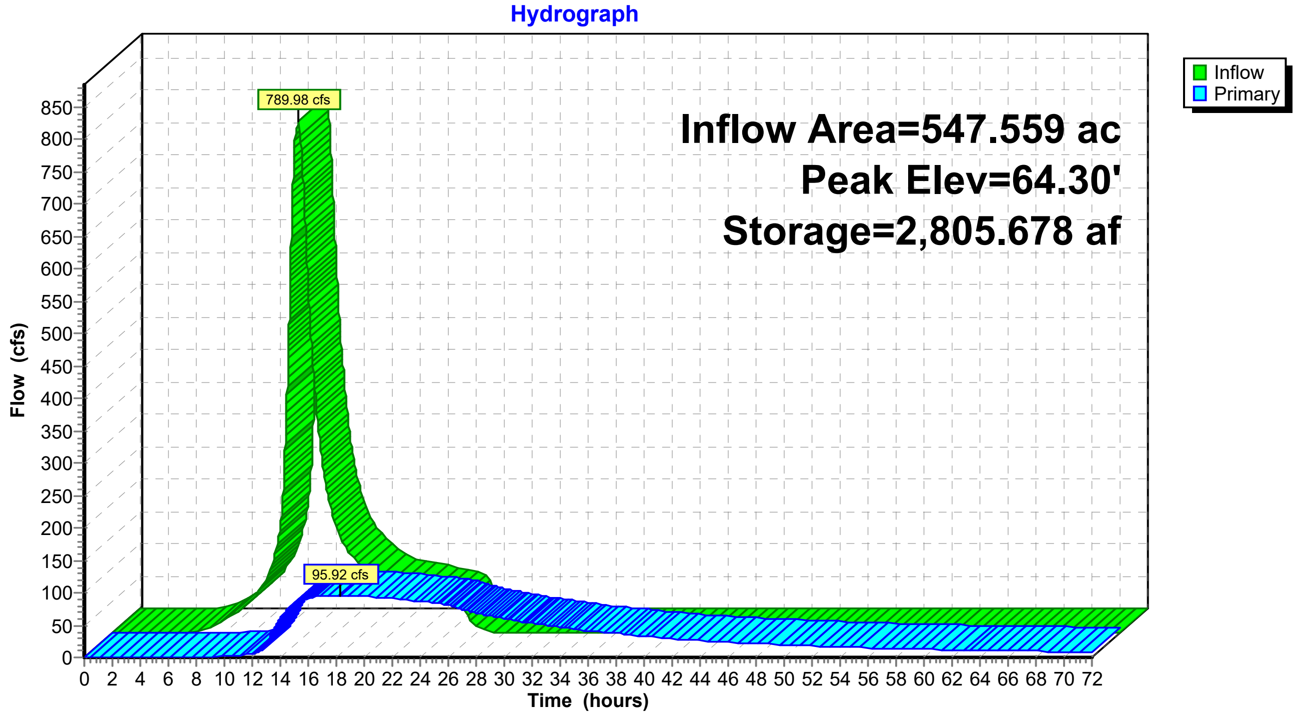
Elevation (feet)	Cum.Store (acre-feet)
37.00	0.000
37.55	0.360
38.00	1.230
38.46	7.350
39.00	18.380
40.14	76.810
41.52	173.140
43.00	298.569
45.62	555.049
50.74	1,111.187
56.01	1,732.306
60.84	2,338.115
61.30	2,397.682
64.67	2,856.603
65.30	2,952.551
70.18	3,805.961
73.67	4,486.270
80.99	6,036.096

Device	Routing	Invert	Outlet Devices
#1	Primary	54.20'	**48.0" Round Overflow Spillway - Culvert** L= 107.6' Box, 0° wingwalls, square crown edge, Ke= 0.700 Inlet / Outlet Invert= 54.20' / 38.70' S= 0.1441 '/' Cc= 0.900 n= 0.012 Concrete pipe, finished, Flow Area= 12.57 sf
#2	Device 1	63.20'	**76.5" x 76.5" Horiz. Overflow Spillway - Wier** C= 0.600 Limited to weir flow at low heads
#3	Primary	65.30'	**330.0' long x 15.0' breadth Dam Crest** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#4	Primary	65.30'	**365.0' long x 15.0' breadth South Dike**

			Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60
			Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#5	Primary	65.30'	**465.0' long x 15.0' breadth North Dike**
			Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60
			Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=95.68 cfs @ 18.22 hrs HW=64.30' TW=39.69' (Dynamic Tailwater)
1=Overflow Spillway - Culvert (Passes 95.68 cfs of 151.91 cfs potential flow)
2=Overflow Spillway - Wier (Weir Controls 95.68 cfs @ 3.42 fps)
3=Dam Crest (Controls 0.00 cfs)
4=South Dike (Controls 0.00 cfs)
5=North Dike (Controls 0.00 cfs)

Pond IHRD: Indian Hill Res. Dam



Summary for Pond LARD: Lower Art. Res. Dam

Inflow Area = 3,908.500 ac, 0.00% Impervious, Inflow Depth > 4.05" for 050-year event
Inflow = 768.68 cfs @ 18.63 hrs, Volume= 1,319.732 af
Outflow = 754.90 cfs @ 20.48 hrs, Volume= 1,310.762 af, Atten= 2%, Lag= 111.2 min
Primary = 754.90 cfs @ 20.48 hrs, Volume= 1,310.762 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 2
Starting Elev= 8.75' Surf.Area= 0.000 ac Storage= 197.211 af
Peak Elev= 11.05' @ 20.48 hrs Surf.Area= 0.000 ac Storage= 301.972 af (104.761 af above start)

Plug-Flow detention time= 440.3 min calculated for 1,113.551 af (84% of inflow)
Center-of-Mass det. time= 106.5 min (1,659.0 - 1,552.5)

Volume	Invert	Avail.Storage	Storage Description
#1	-2.00'	2,624.294 af	**Custom Stage Data**Listed below

Elevation (feet)	Cum.Store (acre-feet)
-2.00	0.000
-0.99	0.060
-0.08	0.430
0.49	1.010
1.04	1.880
1.54	3.310
2.17	6.290
3.00	14.340
3.55	24.880
4.30	43.260
5.00	63.220
6.21	102.690
8.34	180.650
8.75	197.211
10.14	257.879
11.00	299.089
13.00	412.505
14.09	478.889
17.14	676.948
22.86	1,082.038
28.42	1,514.737
32.01	1,815.966
37.32	2,295.375
40.72	2,624.294

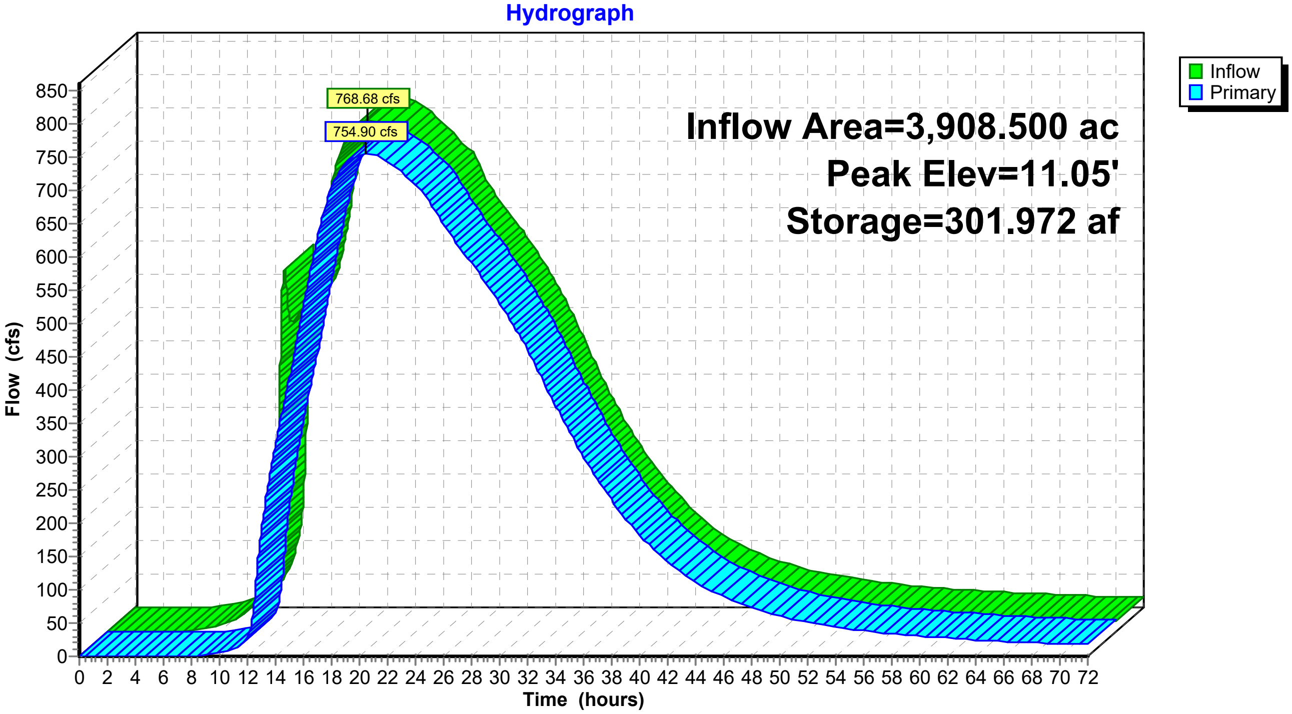
Device	Routing	Invert	Outlet Devices
#1	Primary	8.75'	**80.0' long x 4.4' breadth Primary Spillway** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.36 2.52 2.69 2.68 2.67 2.67 2.65 2.66 2.66 2.67 2.70 2.70 2.73 2.75 2.82 2.96 3.14
#2	Primary	12.00'	**Right Embankment, C= 2.70**

Offset (feet) 0.00 0.00 37.20 62.40 123.40 162.10 185.40 209.30 286.00 342.20 434.00 466.00 561.80 653.80 679.00 697.80 723.10 743.20 772.90 820.60 850.90 915.90 953.90 968.00 996.50 1,031.50 1,084.20 1,098.10 1,127.30 1,146.00 1,156.10 1,176.80 1,208.80 1,248.30 1,325.80 1,398.50 1,425.70
Elev. (feet) 14.40 12.80 12.80 14.00 13.90 12.40 13.30 13.80 14.20 14.40 14.70 14.40 14.60 14.40 13.80 12.70 13.60 12.80 14.10 14.50 14.60 13.30 12.00 12.00 12.00 12.00 12.00 12.00 12.00 12.00 12.00 12.00 12.00 12.00 12.00 12.60 14.40

#3 Primary 10.80' **Left Embankment, C= 2.70**
Offset (feet) 0.00 52.20 173.90 242.50 298.70 334.50 385.00 418.00 448.40 508.40 565.40 601.60 620.30 657.40 716.60 759.70 795.50 865.70 909.20 961.20 1,006.00 1,049.30 1,086.60 1,118.50 1,154.70 1,176.80 1,216.30 1,239.60 1,262.30 1,319.50 1,387.50 1,462.50 1,509.80 1,544.60 1,580.40 1,672.00 1,687.00 1,728.60 1,775.40 1,823.10 1,855.10 1,893.10 1,954.90 2,022.80 2,069.00 2,161.90 2,192.30 2,395.80 2,422.50 2,454.90 2,500.50 2,554.40 2,584.60 2,610.40 2,635.30 2,660.20 2,718.70 2,758.40 2,815.10 2,870.60 2,900.60 2,900.60
Elev. (feet) 14.40 14.30 14.20 14.20 14.30 14.30 14.00 14.20 14.00 14.30 14.30 14.10 12.60 13.90 13.40 13.25 13.10 12.90 12.70 12.00 12.87 12.53 11.23 11.80 11.86 12.50 12.90 13.23 13.60 13.90 13.80 12.50 12.40 11.20 11.80 10.80 11.20 12.50 13.40 13.60 13.20 13.10 13.40 13.70 13.50 13.90 13.70 14.00 14.20 14.20 13.50 13.50 13.30 14.20 13.90 14.40 13.60 12.80 12.30 12.80 13.00 14.40

Primary OutFlow Max=754.90 cfs @ 20.48 hrs HW=11.05' TW=8.23' (Dynamic Tailwater)
—**1=Primary Spillway** (Weir Controls 750.51 cfs @ 4.08 fps)
—**2=Right Embankment** (Controls 0.00 cfs)
—**3=Left Embankment** (Weir Controls 4.39 cfs @ 0.54 fps)

Pond LARD: Lower Art. Res. Dam



Summary for Pond UARD: Upper Art. Res. Dam

[80] Warning: Exceeded Pond 4B by 0.01' @ 9.32 hrs (54.42 cfs 9.511 af)

Inflow Area = 3,718.625 ac, 0.00% Impervious, Inflow Depth > 4.01" for 050-year event
Inflow = 742.49 cfs @ 18.70 hrs, Volume= 1,242.599 af
Outflow = 742.26 cfs @ 18.90 hrs, Volume= 1,241.379 af, Atten= 0%, Lag= 12.0 min
Primary = 742.26 cfs @ 18.90 hrs, Volume= 1,241.379 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 2
Starting Elev= 12.40' Surf.Area= 0.000 ac Storage= 58.576 af
Peak Elev= 14.03' @ 18.90 hrs Surf.Area= 0.000 ac Storage= 74.364 af (15.788 af above start)

Plug-Flow detention time= 147.1 min calculated for 1,182.639 af (95% of inflow)
Center-of-Mass det. time= 16.7 min (1,596.2 - 1,579.5)

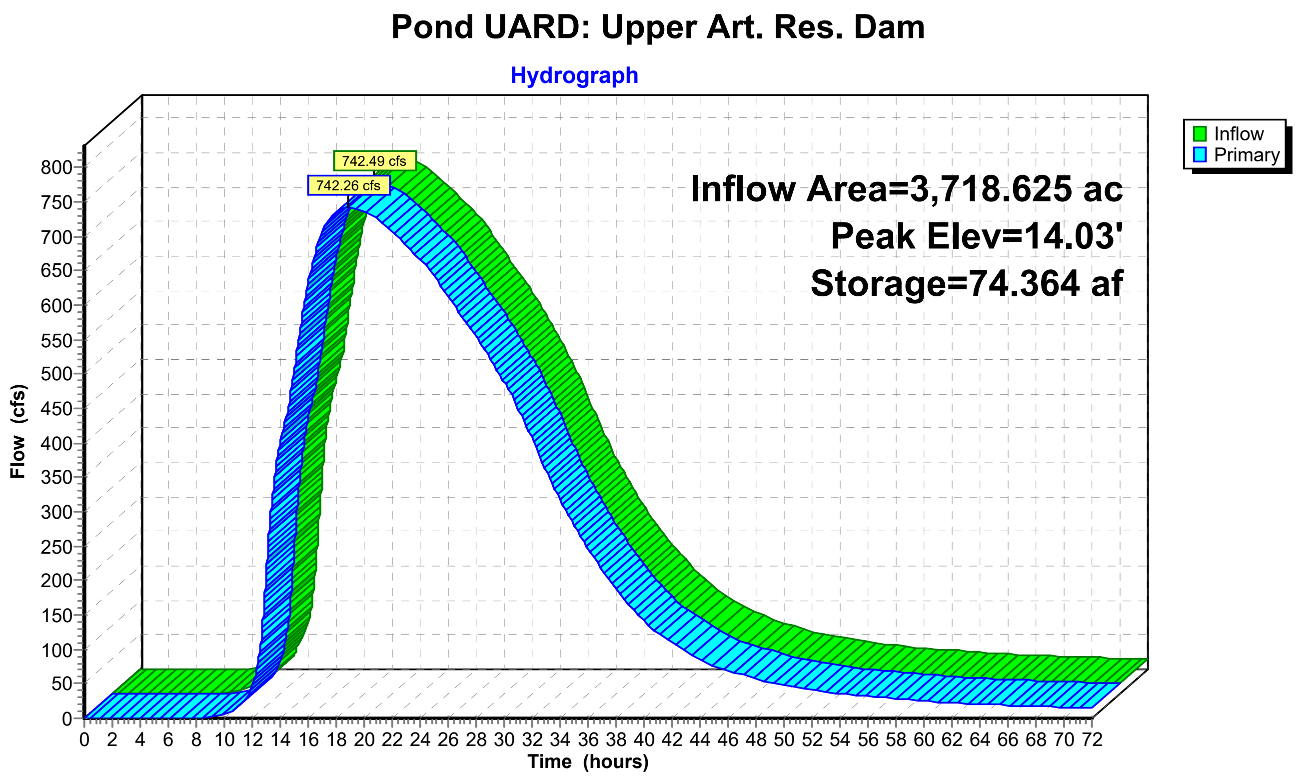
Volume	Invert	Avail.Storage	Storage Description
#1	1.00'	505.869 af	**Custom Stage Data**Listed below

Elevation (feet)	Cum.Store (acre-feet)
1.00	0.000
2.00	0.050
2.96	0.560
3.44	1.250
4.24	3.220
4.48	4.100
6.10	11.760
8.20	24.920
10.47	41.900
12.20	56.660
12.40	58.576
12.87	63.080
13.00	64.340
13.99	73.960
14.90	82.953
15.01	84.040
18.59	121.910
23.69	181.930
26.84	222.839
30.06	267.949
38.25	397.159
44.28	505.869

Device	Routing	Invert	Outlet Devices
#1	Primary	14.90'	**90.0' long x 20.0' breadth Dam Crest** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#2	Primary	12.40'	**135.0' long x 8.0' breadth Primary Spillway** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50

Coef. (English) 2.43 2.54 2.70 2.69 2.68 2.68 2.66 2.64 2.64
2.64 2.65 2.65 2.66 2.66 2.68 2.70 2.74

Primary OutFlow Max=742.25 cfs @ 18.90 hrs HW=14.03' TW=11.02' (Dynamic Tailwater)
↑—**1=Dam Crest** (Controls 0.00 cfs)
└—**2=Primary Spillway** (Weir Controls 742.25 cfs @ 3.37 fps)

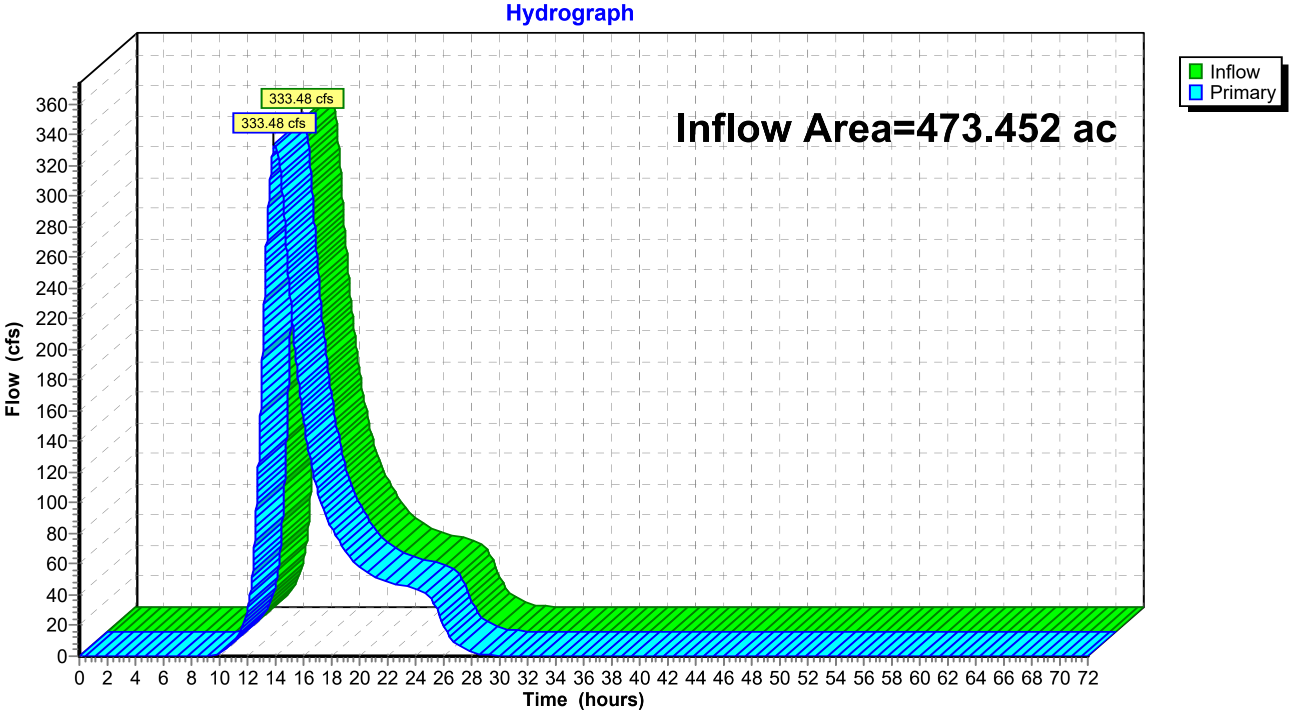


Summary for Link HEC1: HECRAS 1

Inflow Area =	473.452 ac,	0.00% Impervious, Inflow Depth = 3.20"	for 050-year event	
Inflow =	333.48 cfs @	13.92 hrs, Volume=	126.386 af	
Primary =	333.48 cfs @	13.92 hrs, Volume=	126.386 af,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs

Link HEC1: HECRAS 1

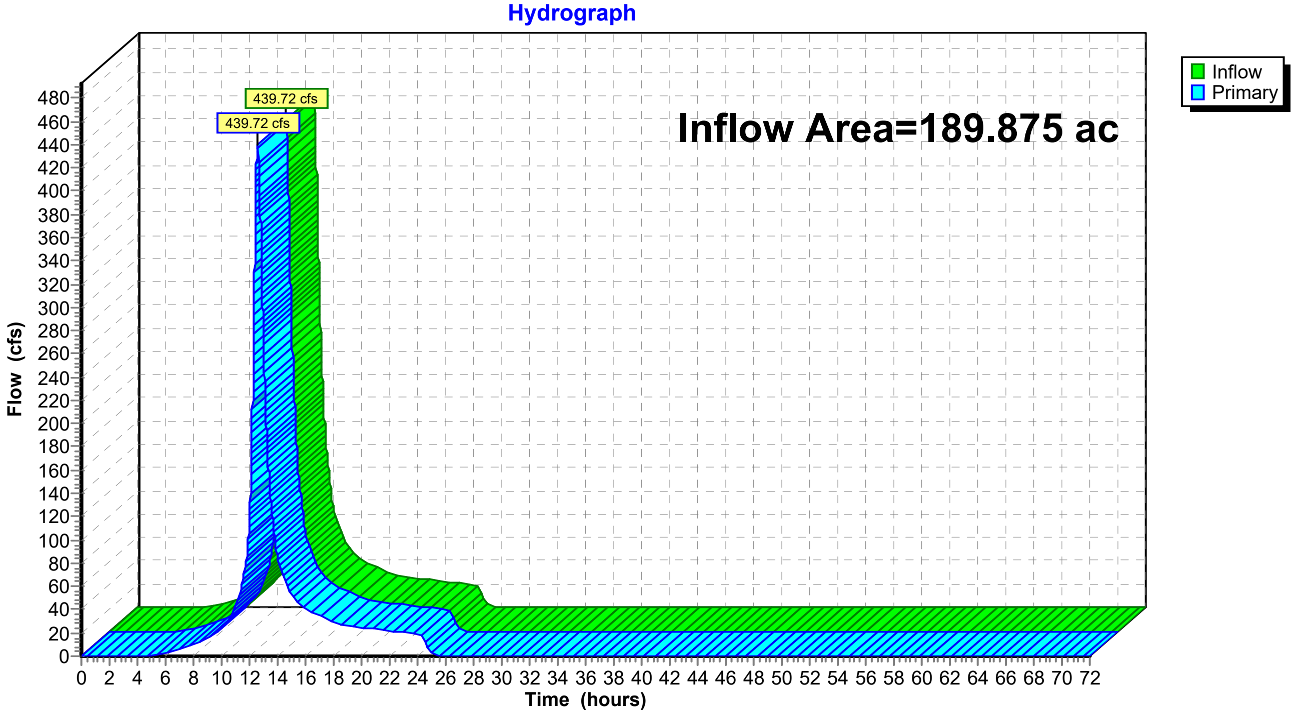


Summary for Link HEC2: HECRAS 2

Inflow Area =	189.875 ac,	0.00% Impervious, Inflow Depth = 4.95"	for 050-year event
Inflow =	439.72 cfs @	12.59 hrs, Volume=	78.353 af
Primary =	439.72 cfs @	12.59 hrs, Volume=	78.353 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs

Link HEC2: HECRAS 2

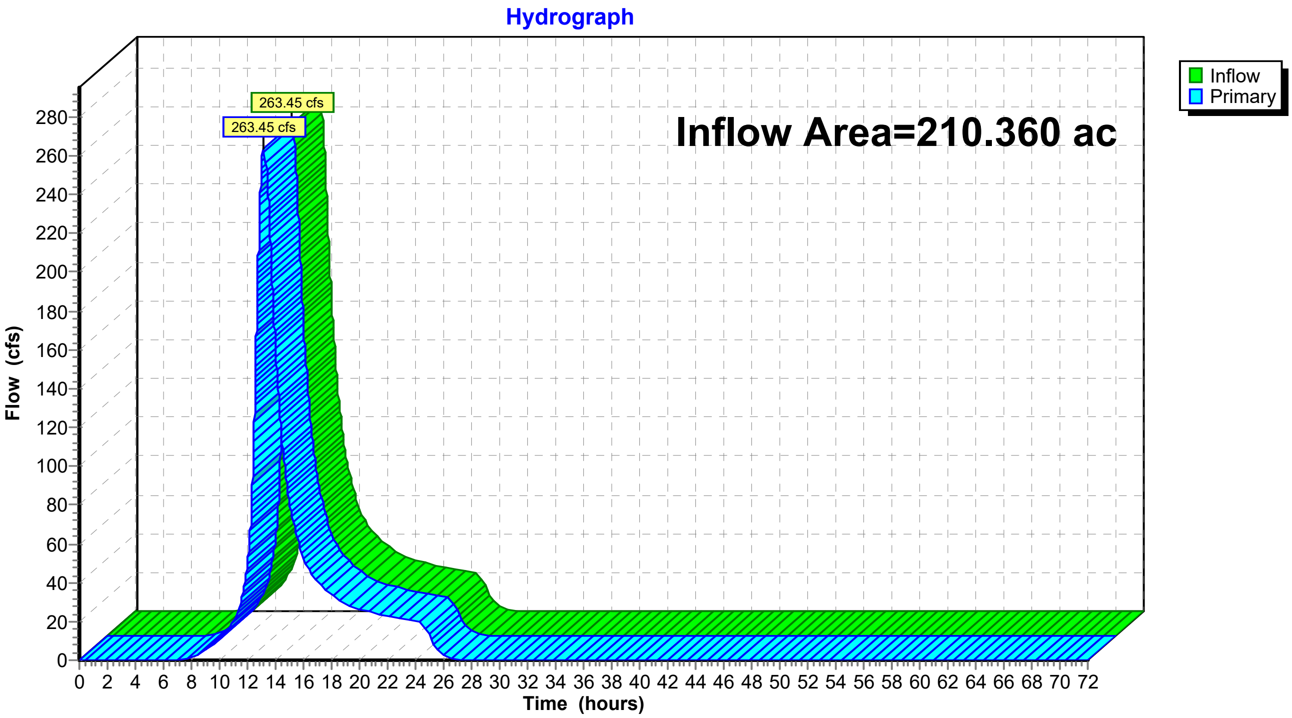


Summary for Link HEC3: HECRAS 3

Inflow Area =	210.360 ac,	0.00% Impervious, Inflow Depth = 4.06"	for 050-year event
Inflow =	263.45 cfs @	13.18 hrs, Volume=	71.216 af
Primary =	263.45 cfs @	13.18 hrs, Volume=	71.216 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs

Link HEC3: HECRAS 3

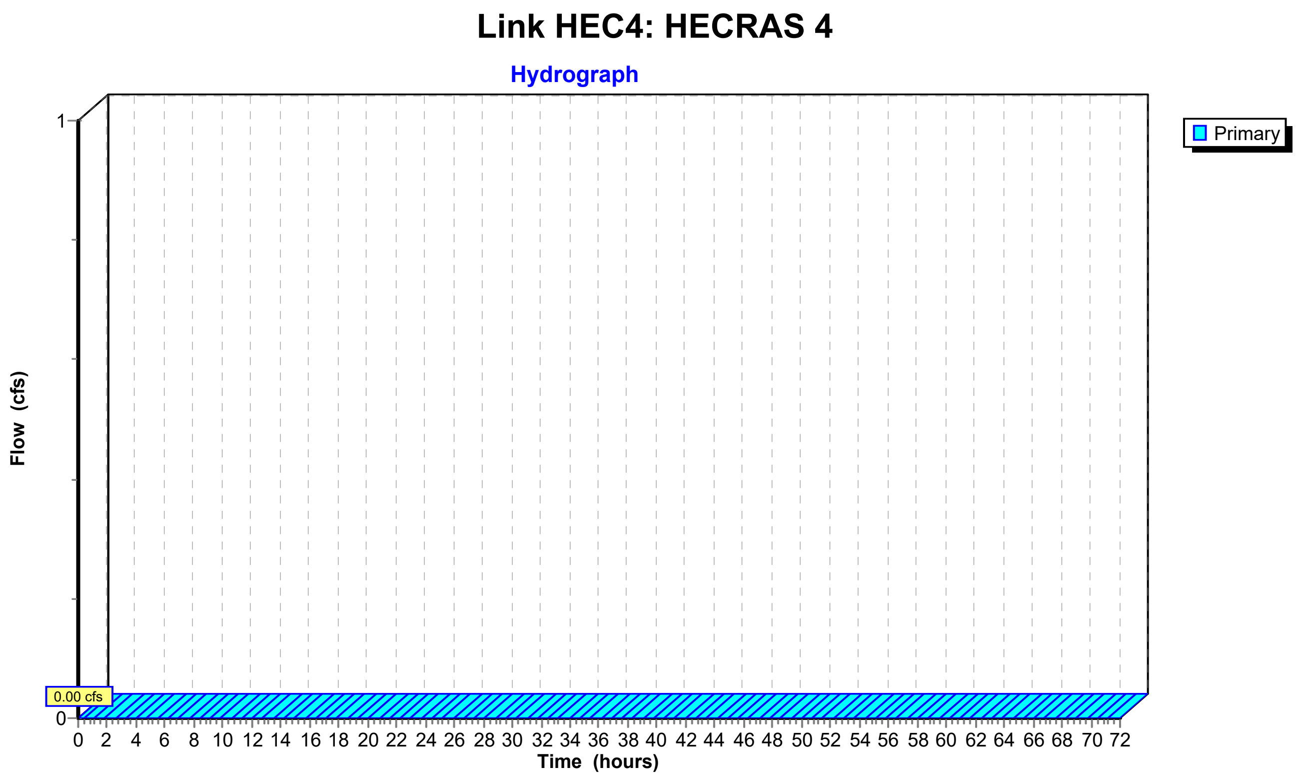


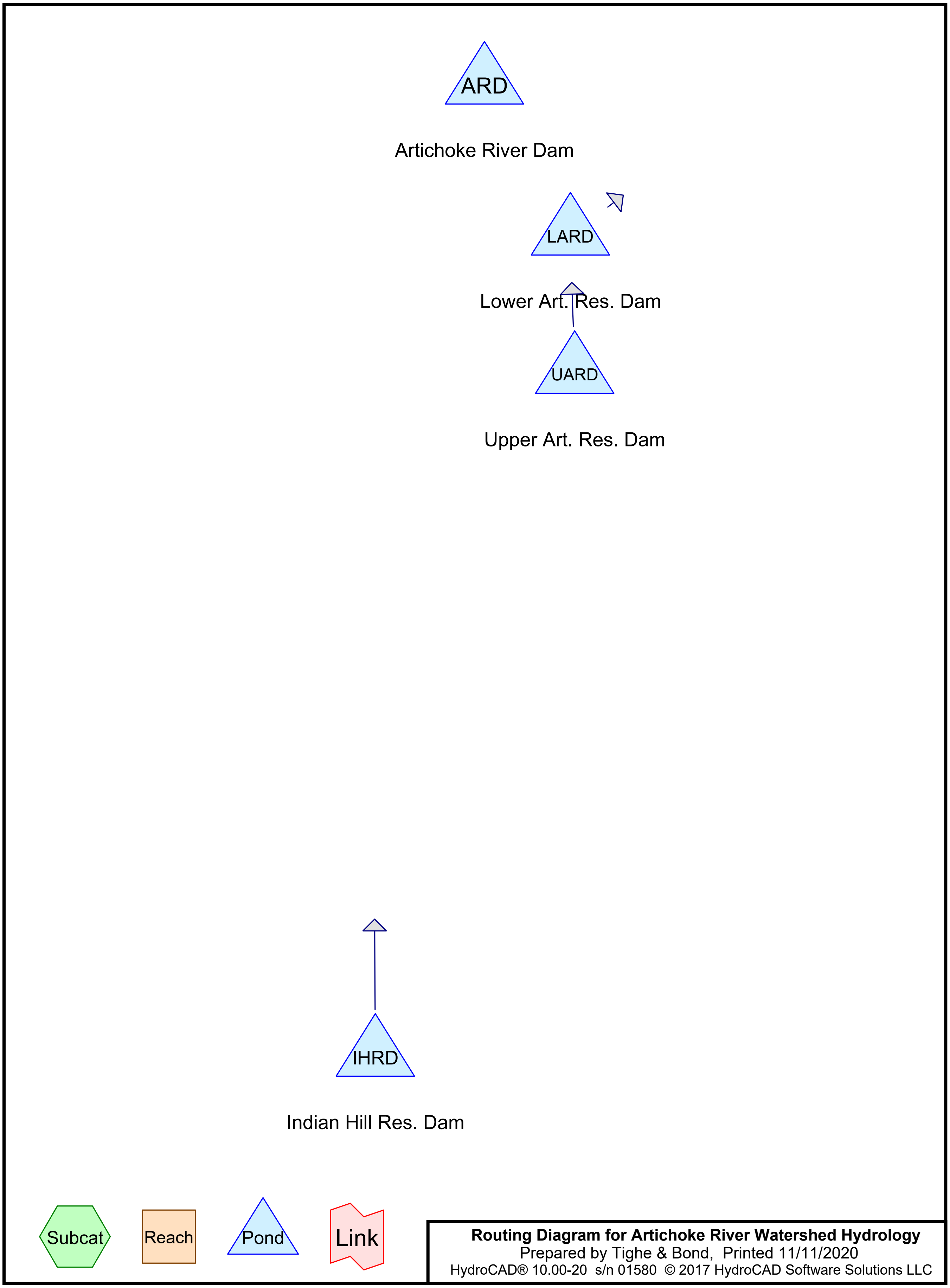
Summary for Link HEC4: HECRAS 4

[43] Hint: Has no inflow (Outflow=Zero)

Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Primary outflow = Inflow, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs





Routing Diagram for Artichoke River Watershed Hydrology
Prepared by Tighe & Bond, Printed 11/11/2020
HydroCAD® 10.00-20 s/n 01580 © 2017 HydroCAD Software Solutions LLC

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
0.000	**0**	**TOTAL AREA**

Soil Listing (selected nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
0.000	HSG B	
0.000	HSG C	
0.000	HSG D	
0.000	Other	
0.000		**TOTAL AREA**

Ground Covers (selected nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
0.000	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**TOTAL AREA**	

Pipe Listing (selected nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)	Inside-Fill (inches)
1	IHRD	54.20	38.70	107.6	0.1441	0.012	48.0	0.0	0.0

Time span=0.00-72.00 hrs, dt=0.01 hrs, 7201 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Pond ARD: Artichoke River Dam Peak Elev=8.03' Storage=79.314 af Inflow=825.29 cfs 1,437.148 af
Outflow=807.52 cfs 1,435.950 af

Pond IHRD: Indian Hill Res. Dam Peak Elev=64.30' Storage=2,805.678 af Inflow=789.98 cfs 225.953 af
Outflow=95.92 cfs 197.807 af

Pond LARD: Lower Art. Res. Dam Peak Elev=11.05' Storage=301.972 af Inflow=768.68 cfs 1,319.732 af
Outflow=754.90 cfs 1,310.762 af

Pond UARD: Upper Art. Res. Dam Peak Elev=14.03' Storage=74.364 af Inflow=742.49 cfs 1,242.599 af
Outflow=742.26 cfs 1,241.379 af

Summary for Pond ARD: Artichoke River Dam

[80] Warning: Exceeded Pond 2B by 4.69' @ 0.00 hrs (1,128.38 cfs 192.643 af)

Inflow Area = 4,381.952 ac, 0.00% Impervious, Inflow Depth > 3.94" for 050-year event
Inflow = 825.29 cfs @ 19.70 hrs, Volume= 1,437.148 af
Outflow = 807.52 cfs @ 20.81 hrs, Volume= 1,435.950 af, Atten= 2%, Lag= 66.4 min
Primary = 807.52 cfs @ 20.81 hrs, Volume= 1,435.950 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 2
Starting Elev= 4.40' Surf.Area= 0.000 ac Storage= 17.307 af
Peak Elev= 8.03' @ 20.81 hrs Surf.Area= 0.000 ac Storage= 79.314 af (62.007 af above start)

Plug-Flow detention time= 94.9 min calculated for 1,418.643 af (99% of inflow)
Center-of-Mass det. time= 52.8 min (1,653.8 - 1,601.0)

Volume	Invert	Avail.Storage	Storage Description
#1	-0.51'	2,226.935 af	**Custom Stage Data**Listed below

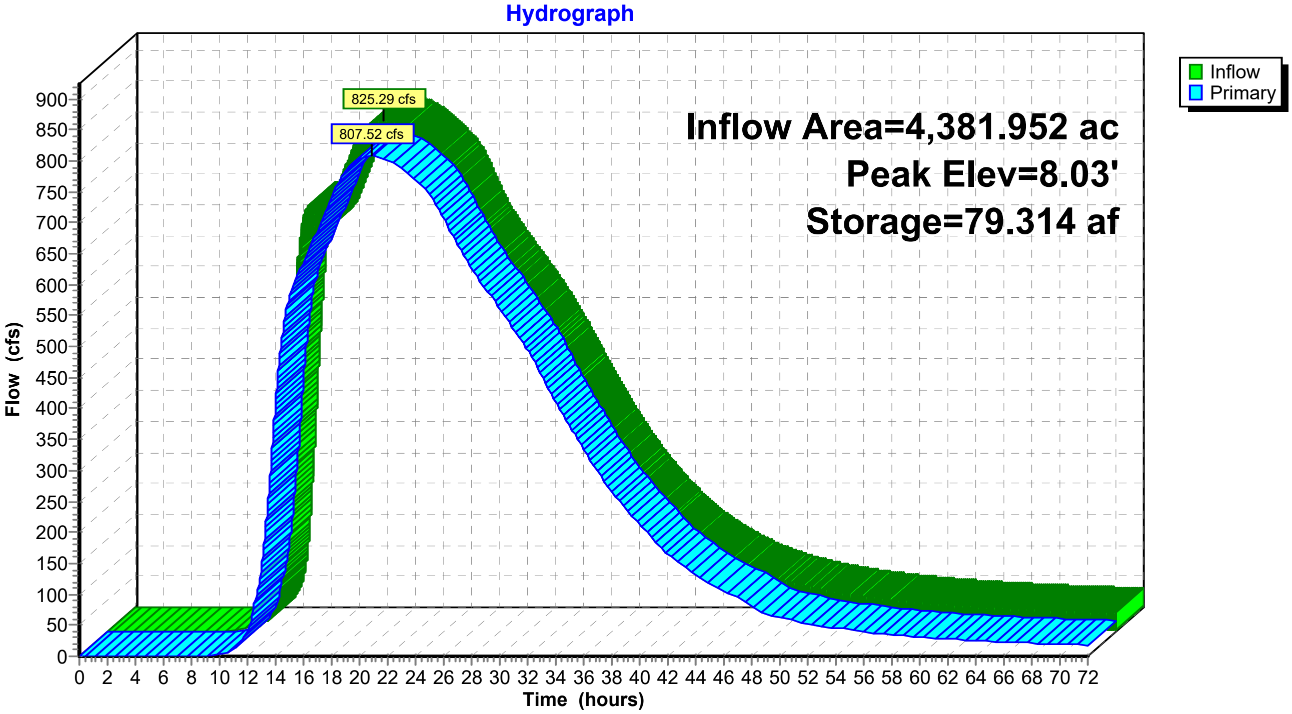
Elevation (feet)	Cum.Store (acre-feet)
-0.51	0.000
5.34	20.620
6.04	32.770
7.14	55.410
8.11	81.340
9.10	117.040
11.17	211.100
14.07	368.899
17.86	607.589
21.68	880.678
24.35	1,089.067
28.70	1,455.627
31.62	1,718.426
34.49	1,990.465
35.87	2,127.365
36.85	2,226.935

Device	Routing	Invert	Outlet Devices
#1	Primary	4.40'	**36.0' long x 3.0' breadth Primary Spillway** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	6.20'	**9.0' long x 3.0' breadth Training Walls** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#3	Primary	11.00'	**40.0' long x 12.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60

Coef. (English) 2.57 2.62 2.70 2.67 2.66 2.67 2.66 2.64

Primary OutFlow Max=807.52 cfs @ 20.81 hrs HW=8.03' (Free Discharge)
1=Primary Spillway (Weir Controls 747.45 cfs @ 5.71 fps)
2=Training Walls (Weir Controls 60.07 cfs @ 3.64 fps)
3=Broad-Crested Rectangular Weir (Controls 0.00 cfs)

Pond ARD: Artichoke River Dam



Summary for Pond IHRD: Indian Hill Res. Dam

[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=2)

Inflow Area = 547.559 ac, 0.00% Impervious, Inflow Depth = 4.95" for 050-year event
Inflow = 789.98 cfs @ 13.30 hrs, Volume= 225.953 af
Outflow = 95.92 cfs @ 18.22 hrs, Volume= 197.807 af, Atten= 88%, Lag= 295.5 min
Primary = 95.92 cfs @ 18.22 hrs, Volume= 197.807 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 2
Starting Elev= 63.20' Surf.Area= 0.000 ac Storage= 2,656.421 af
Peak Elev= 64.30' @ 18.22 hrs Surf.Area= 0.000 ac Storage= 2,805.678 af (149.257 af above start)

Plug-Flow detention time= (not calculated: initial storage exceeds outflow)
Center-of-Mass det. time= 934.4 min (1,843.6 - 909.2)

Volume	Invert	Avail.Storage	Storage Description
#1	37.00'	6,036.096 af	**Custom Stage Data**Listed below

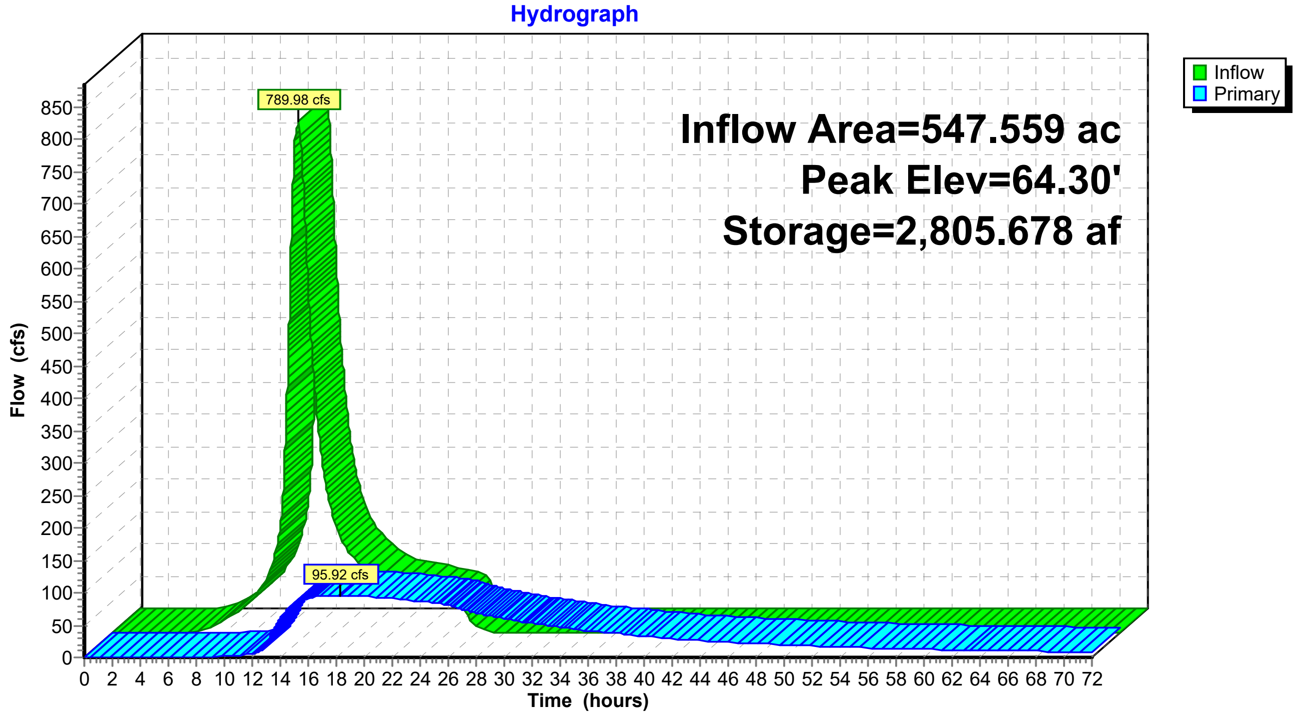
Elevation (feet)	Cum.Store (acre-feet)
37.00	0.000
37.55	0.360
38.00	1.230
38.46	7.350
39.00	18.380
40.14	76.810
41.52	173.140
43.00	298.569
45.62	555.049
50.74	1,111.187
56.01	1,732.306
60.84	2,338.115
61.30	2,397.682
64.67	2,856.603
65.30	2,952.551
70.18	3,805.961
73.67	4,486.270
80.99	6,036.096

Device	Routing	Invert	Outlet Devices
#1	Primary	54.20'	**48.0" Round Overflow Spillway - Culvert** L= 107.6' Box, 0° wingwalls, square crown edge, Ke= 0.700 Inlet / Outlet Invert= 54.20' / 38.70' S= 0.1441 '/' Cc= 0.900 n= 0.012 Concrete pipe, finished, Flow Area= 12.57 sf
#2	Device 1	63.20'	**76.5" x 76.5" Horiz. Overflow Spillway - Wier** C= 0.600 Limited to weir flow at low heads
#3	Primary	65.30'	**330.0' long x 15.0' breadth Dam Crest** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#4	Primary	65.30'	**365.0' long x 15.0' breadth South Dike**

			Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60
			Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#5	Primary	65.30'	**465.0' long x 15.0' breadth North Dike**
			Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60
			Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=95.68 cfs @ 18.22 hrs HW=64.30' TW=39.69' (Dynamic Tailwater)
—**1=Overflow Spillway - Culvert** (Passes 95.68 cfs of 151.91 cfs potential flow)
 —**2=Overflow Spillway - Wier** (Weir Controls 95.68 cfs @ 3.42 fps)
—**3=Dam Crest** (Controls 0.00 cfs)
—**4=South Dike** (Controls 0.00 cfs)
—**5=North Dike** (Controls 0.00 cfs)

Pond IHRD: Indian Hill Res. Dam



Summary for Pond LARD: Lower Art. Res. Dam

Inflow Area = 3,908.500 ac, 0.00% Impervious, Inflow Depth > 4.05" for 050-year event
Inflow = 768.68 cfs @ 18.63 hrs, Volume= 1,319.732 af
Outflow = 754.90 cfs @ 20.48 hrs, Volume= 1,310.762 af, Atten= 2%, Lag= 111.2 min
Primary = 754.90 cfs @ 20.48 hrs, Volume= 1,310.762 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 2
Starting Elev= 8.75' Surf.Area= 0.000 ac Storage= 197.211 af
Peak Elev= 11.05' @ 20.48 hrs Surf.Area= 0.000 ac Storage= 301.972 af (104.761 af above start)

Plug-Flow detention time= 440.3 min calculated for 1,113.551 af (84% of inflow)
Center-of-Mass det. time= 106.5 min (1,659.0 - 1,552.5)

Volume	Invert	Avail.Storage	Storage Description
#1	-2.00'	2,624.294 af	**Custom Stage Data**Listed below

Elevation (feet)	Cum.Store (acre-feet)
-2.00	0.000
-0.99	0.060
-0.08	0.430
0.49	1.010
1.04	1.880
1.54	3.310
2.17	6.290
3.00	14.340
3.55	24.880
4.30	43.260
5.00	63.220
6.21	102.690
8.34	180.650
8.75	197.211
10.14	257.879
11.00	299.089
13.00	412.505
14.09	478.889
17.14	676.948
22.86	1,082.038
28.42	1,514.737
32.01	1,815.966
37.32	2,295.375
40.72	2,624.294

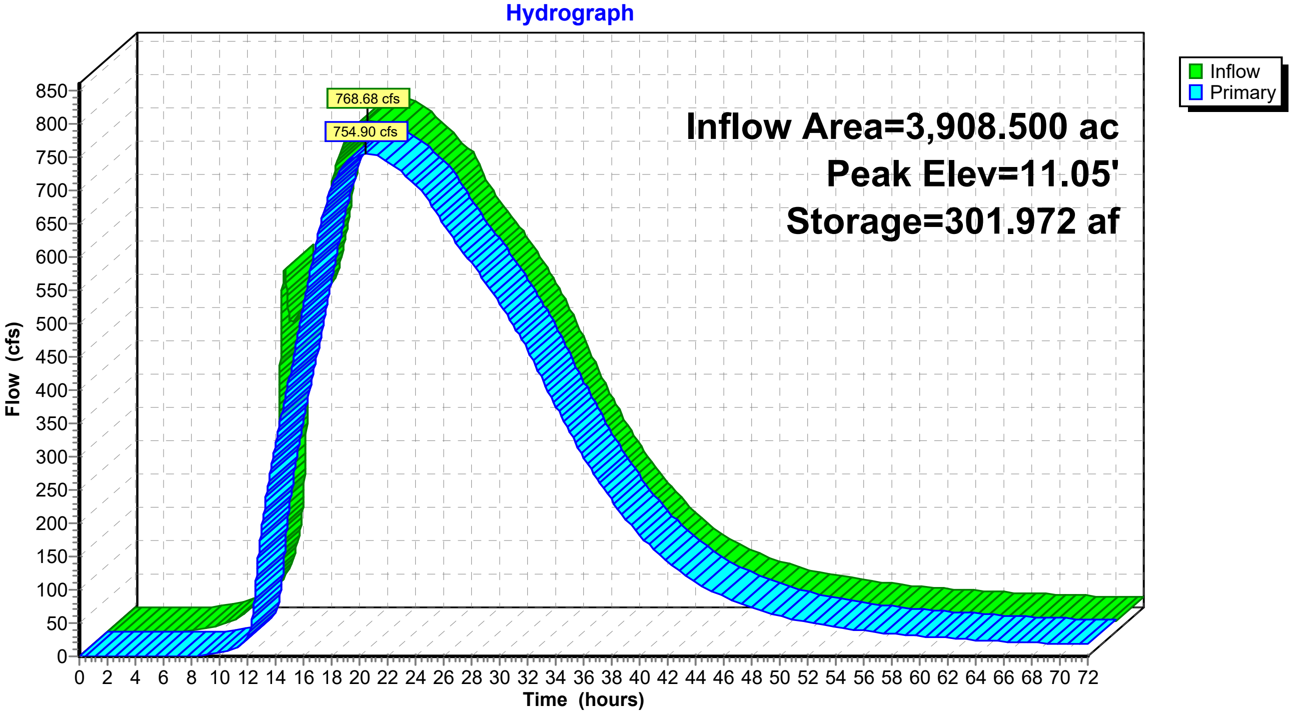
Device	Routing	Invert	Outlet Devices
#1	Primary	8.75'	**80.0' long x 4.4' breadth Primary Spillway** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.36 2.52 2.69 2.68 2.67 2.67 2.65 2.66 2.66 2.67 2.70 2.70 2.73 2.75 2.82 2.96 3.14
#2	Primary	12.00'	**Right Embankment, C= 2.70**

Offset (feet) 0.00 0.00 37.20 62.40 123.40 162.10 185.40 209.30 286.00 342.20 434.00 466.00 561.80 653.80 679.00 697.80 723.10 743.20 772.90 820.60 850.90 915.90 953.90 968.00 996.50 1,031.50 1,084.20 1,098.10 1,127.30 1,146.00 1,156.10 1,176.80 1,208.80 1,248.30 1,325.80 1,398.50 1,425.70
Elev. (feet) 14.40 12.80 12.80 14.00 13.90 12.40 13.30 13.80 14.20 14.40 14.70 14.40 14.60 14.40 13.80 12.70 13.60 12.80 14.10 14.50 14.60 13.30 12.00 12.00 12.00 12.00 12.00 12.00 12.00 12.00 12.00 12.00 12.00 12.00 12.00 12.60 14.40

#3 Primary 10.80' **Left Embankment, C= 2.70**
Offset (feet) 0.00 52.20 173.90 242.50 298.70 334.50 385.00 418.00 448.40 508.40 565.40 601.60 620.30 657.40 716.60 759.70 795.50 865.70 909.20 961.20 1,006.00 1,049.30 1,086.60 1,118.50 1,154.70 1,176.80 1,216.30 1,239.60 1,262.30 1,319.50 1,387.50 1,462.50 1,509.80 1,544.60 1,580.40 1,672.00 1,687.00 1,728.60 1,775.40 1,823.10 1,855.10 1,893.10 1,954.90 2,022.80 2,069.00 2,161.90 2,192.30 2,395.80 2,422.50 2,454.90 2,500.50 2,554.40 2,584.60 2,610.40 2,635.30 2,660.20 2,718.70 2,758.40 2,815.10 2,870.60 2,900.60 2,900.60
Elev. (feet) 14.40 14.30 14.20 14.20 14.30 14.30 14.00 14.20 14.00 14.30 14.30 14.10 12.60 13.90 13.40 13.25 13.10 12.90 12.70 12.00 12.87 12.53 11.23 11.80 11.86 12.50 12.90 13.23 13.60 13.90 13.80 12.50 12.40 11.20 11.80 10.80 11.20 12.50 13.40 13.60 13.20 13.10 13.40 13.70 13.50 13.90 13.70 14.00 14.20 14.20 13.50 13.50 13.30 14.20 13.90 14.40 13.60 12.80 12.30 12.80 13.00 14.40

Primary OutFlow Max=754.90 cfs @ 20.48 hrs HW=11.05' TW=8.23' (Dynamic Tailwater)
—**1=Primary Spillway** (Weir Controls 750.51 cfs @ 4.08 fps)
—**2=Right Embankment** (Controls 0.00 cfs)
—**3=Left Embankment** (Weir Controls 4.39 cfs @ 0.54 fps)

Pond LARD: Lower Art. Res. Dam



Summary for Pond UARD: Upper Art. Res. Dam

[80] Warning: Exceeded Pond 4B by 0.01' @ 9.32 hrs (54.42 cfs 9.511 af)

Inflow Area = 3,718.625 ac, 0.00% Impervious, Inflow Depth > 4.01" for 050-year event
Inflow = 742.49 cfs @ 18.70 hrs, Volume= 1,242.599 af
Outflow = 742.26 cfs @ 18.90 hrs, Volume= 1,241.379 af, Atten= 0%, Lag= 12.0 min
Primary = 742.26 cfs @ 18.90 hrs, Volume= 1,241.379 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 2
Starting Elev= 12.40' Surf.Area= 0.000 ac Storage= 58.576 af
Peak Elev= 14.03' @ 18.90 hrs Surf.Area= 0.000 ac Storage= 74.364 af (15.788 af above start)

Plug-Flow detention time= 147.1 min calculated for 1,182.639 af (95% of inflow)
Center-of-Mass det. time= 16.7 min (1,596.2 - 1,579.5)

Volume	Invert	Avail.Storage	Storage Description
#1	1.00'	505.869 af	**Custom Stage Data**Listed below

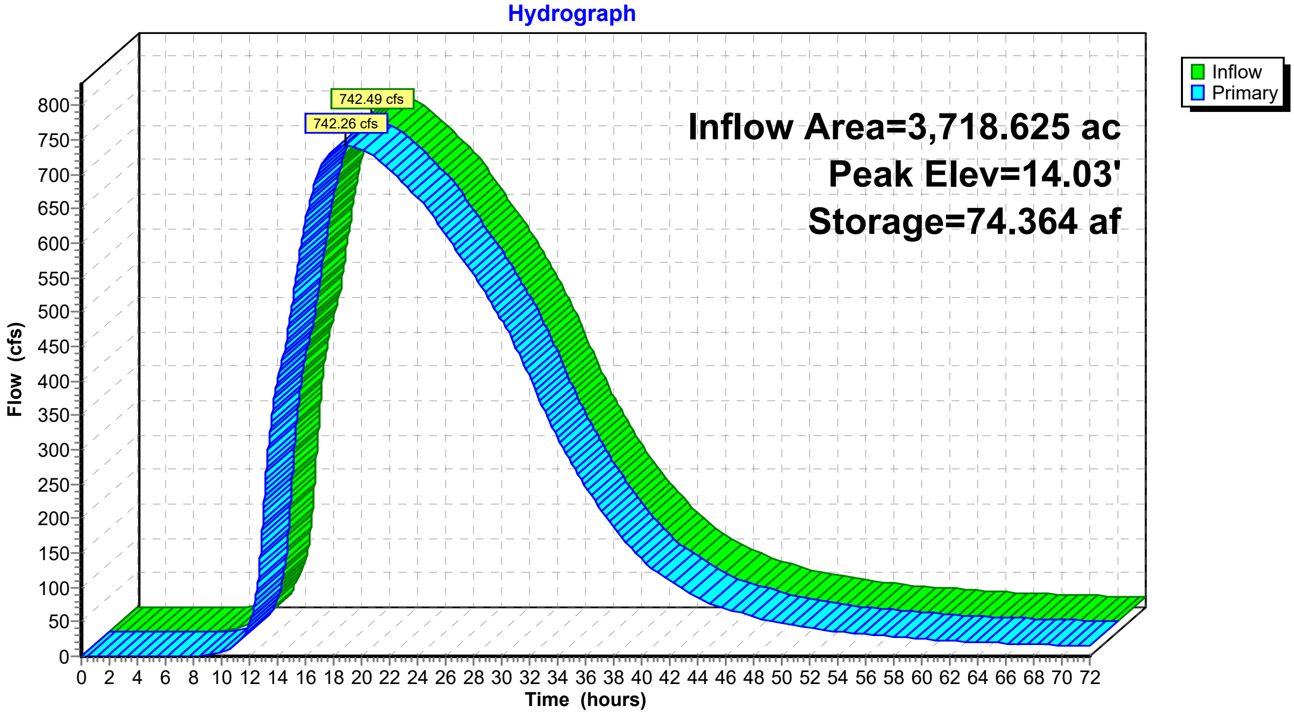
Elevation (feet)	Cum.Store (acre-feet)
1.00	0.000
2.00	0.050
2.96	0.560
3.44	1.250
4.24	3.220
4.48	4.100
6.10	11.760
8.20	24.920
10.47	41.900
12.20	56.660
12.40	58.576
12.87	63.080
13.00	64.340
13.99	73.960
14.90	82.953
15.01	84.040
18.59	121.910
23.69	181.930
26.84	222.839
30.06	267.949
38.25	397.159
44.28	505.869

Device	Routing	Invert	Outlet Devices
#1	Primary	14.90'	**90.0' long x 20.0' breadth Dam Crest** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#2	Primary	12.40'	**135.0' long x 8.0' breadth Primary Spillway** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50

Coef. (English) 2.43 2.54 2.70 2.69 2.68 2.68 2.66 2.64 2.64
2.64 2.65 2.65 2.66 2.66 2.68 2.70 2.74

Primary OutFlow Max=742.25 cfs @ 18.90 hrs HW=14.03' TW=11.02' (Dynamic Tailwater)
1=Dam Crest (Controls 0.00 cfs)
2=Primary Spillway (Weir Controls 742.25 cfs @ 3.37 fps)

Pond UARD: Upper Art. Res. Dam



APPENDIX C

Artichoke River Two-Dimensional (2D) HEC-RAS Model Results

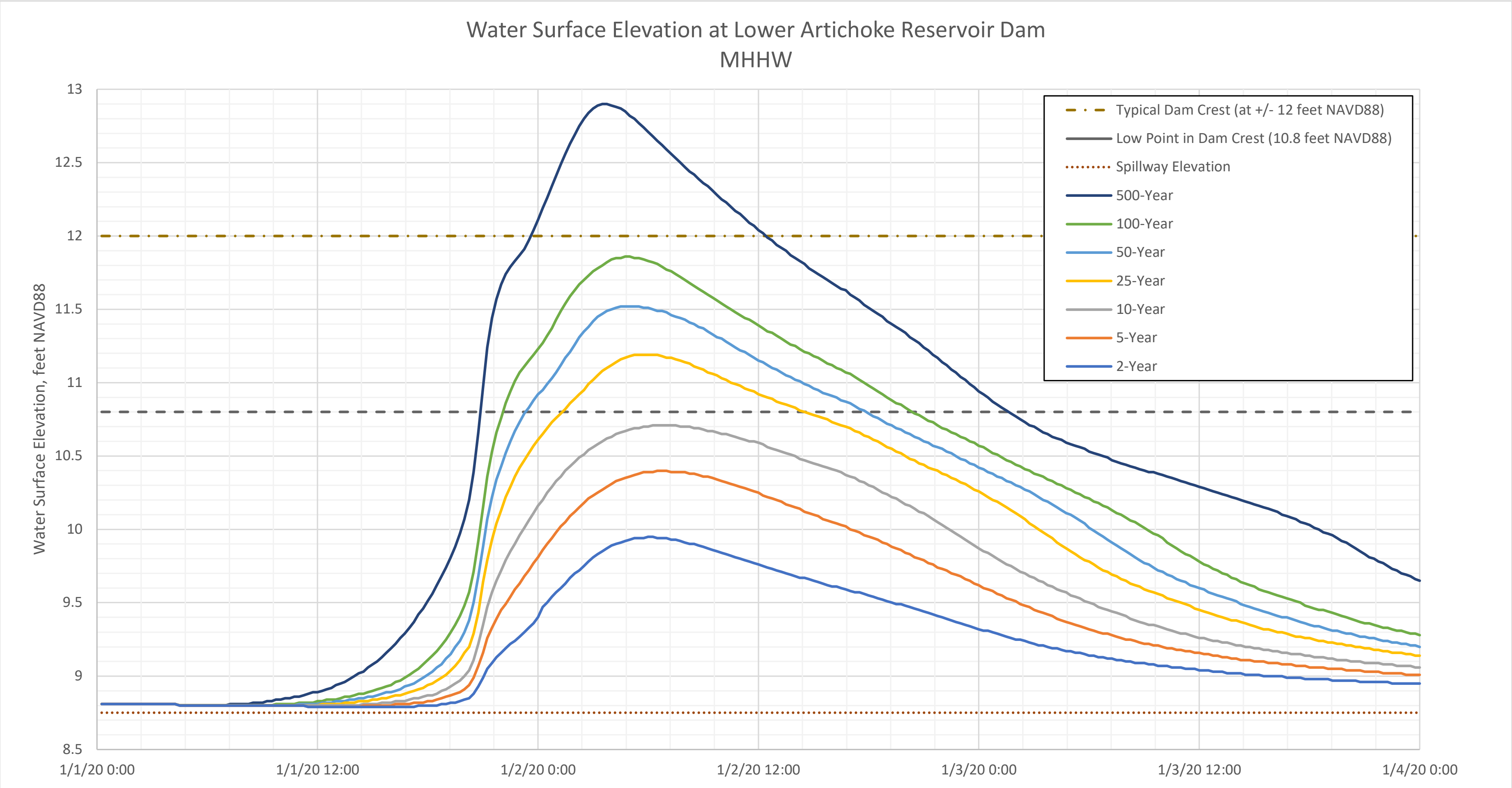


Figure C-1
Water Surface Elevations at Lower Artichoke Reservoir Dam with Mean Higher High Water (MHHW) Downstream Conditions

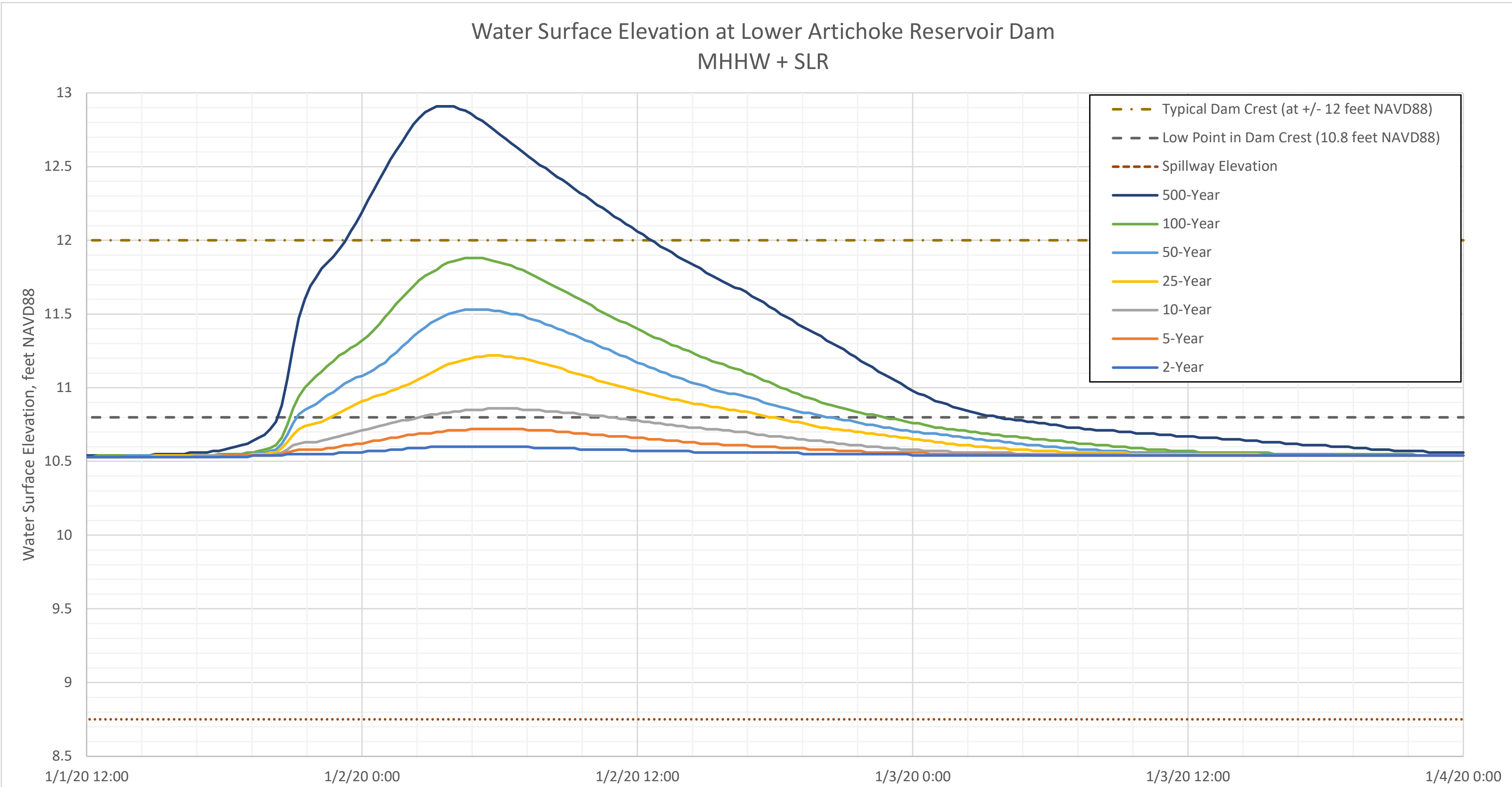


Figure C-2
Water Surface Elevations at Lower Artichoke Reservoir Dam with Mean Higher High Water (MHHW) with Sea Level Rise (SLR) Downstream Conditions

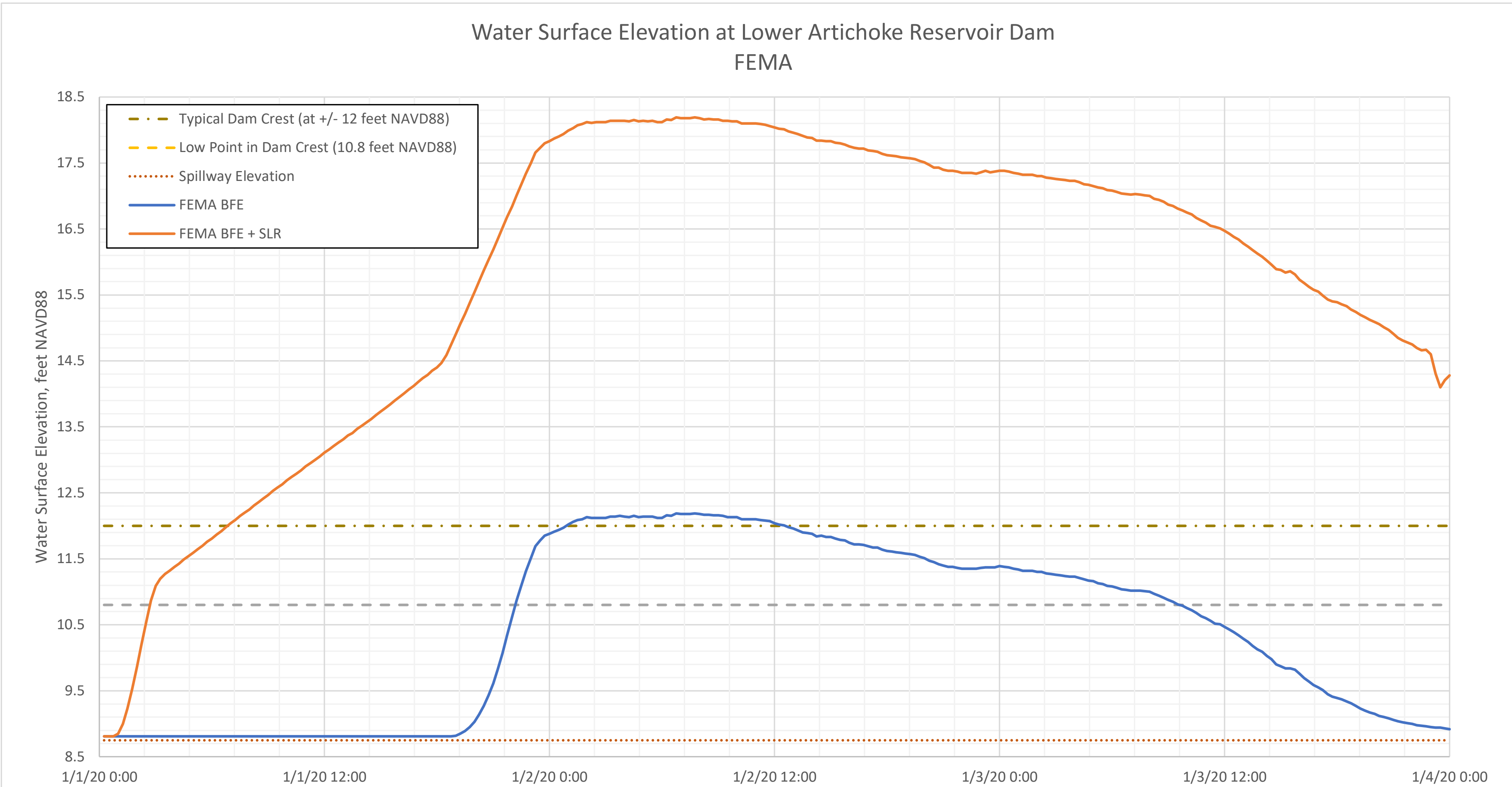


Figure C-3
Water Surface Elevations at Lower Artichoke Reservoir Dam with Flooding from the Merrimack River based on the Federal Emergency Managment Agency (FEMA) Base Flood Elevation (BFE)

Figure C-4: Two Dimensional HEC-RAS Results for "Run No. 1" 2-Year frequency storm event with Mean Higher High Water (MHHW) downstream boundary conditions.

Figure C-5: Two Dimensional HEC-RAS Results for "Run No. 2" 5-Year frequency storm event with Mean Higher High Water (MHHW) downstream boundary conditions.

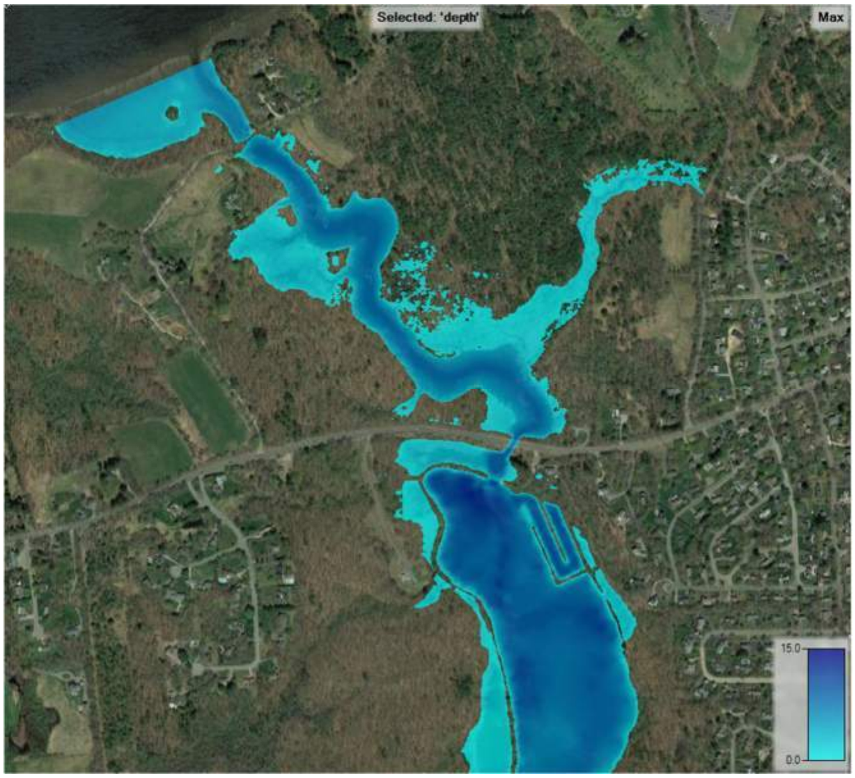


Figure C-6: Two Dimensional HEC-RAS Results for “Run No. 3” 10-Year frequency storm event with Mean Higher High Water (MHHW) downstream boundary conditions.

Figure C-7: Two Dimensional HEC-RAS Results for “Run No. 4” 25-Year frequency storm event with Mean Higher High Water (MHHW) downstream boundary conditions.

Figure C-8: Two Dimensional HEC-RAS Results for “Run No. 5” 50-Year frequency storm event with Mean Higher High Water (MHHW) downstream boundary conditions.

Figure C-9: Two Dimensional HEC-RAS Results for “Run No. 6” 100-Year frequency storm event with Mean Higher High Water (MHHW) downstream boundary conditions.

Figure C-10: Two Dimensional HEC-RAS Results for "Run No. 7" 500-Year frequency storm event with Mean Higher High Water (MHHW) downstream boundary conditions.

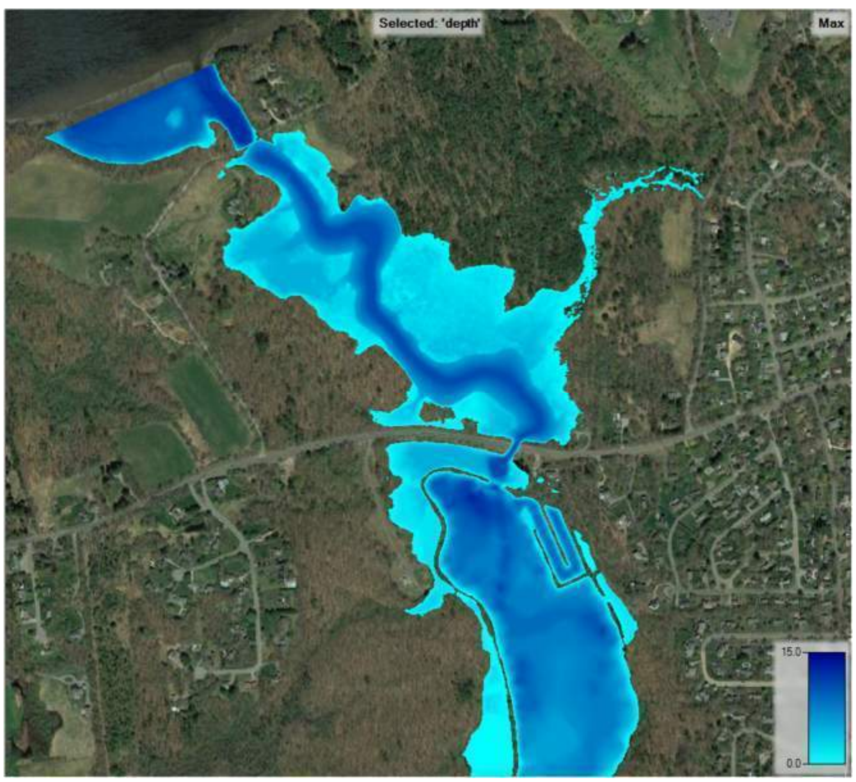


Figure C-11: Two Dimensional HEC-RAS Results for "Run No. 8" 2-Year frequency storm event with Mean Higher High Water (MHHW) plus Sea Level Rise (SLR) downstream boundary conditions.

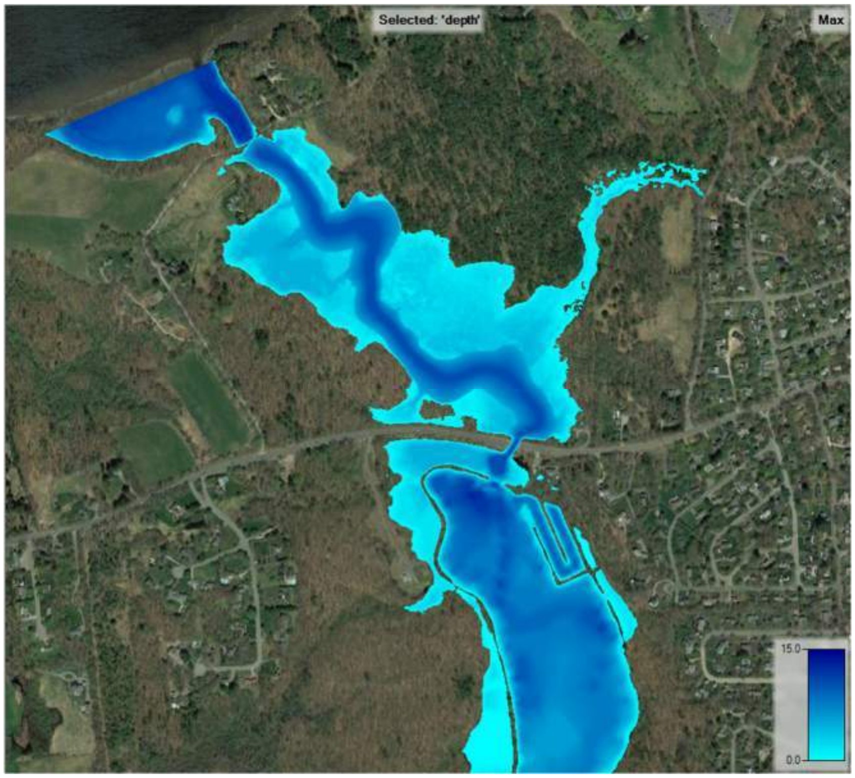


Figure C-12: Two Dimensional HEC-RAS Results for "Run No. 9" 5-Year frequency storm event with Mean Higher High Water (MHHW) plus Sea Level Rise (SLR) downstream boundary conditions.

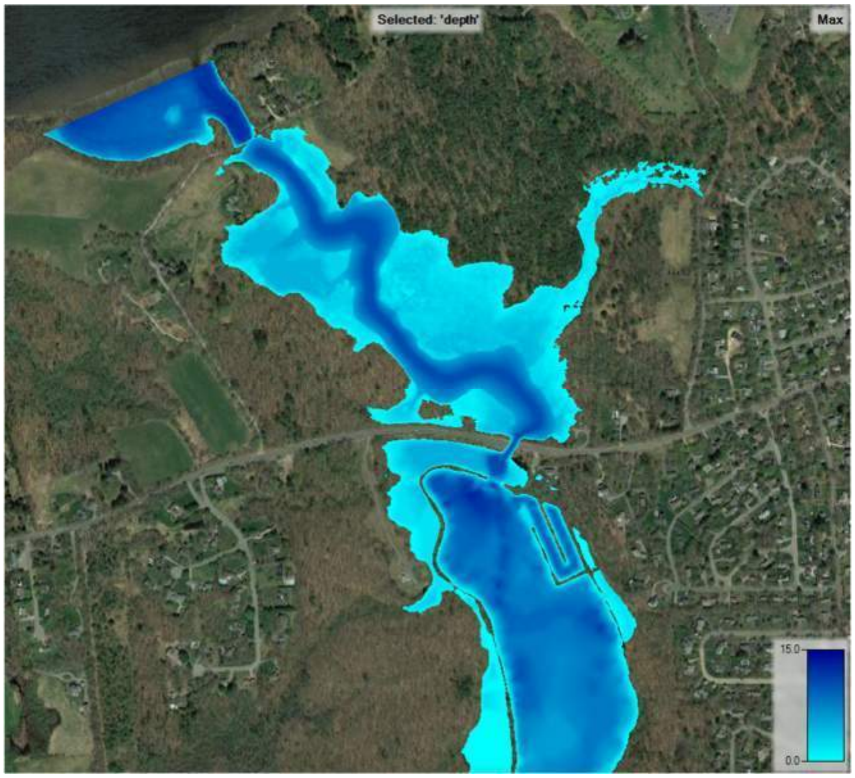


Figure C-13: Two Dimensional HEC-RAS Results for "Run No. 10" 10-Year frequency storm event with Mean Higher High Water (MHHW) plus Sea Level Rise (SLR) downstream boundary conditions.

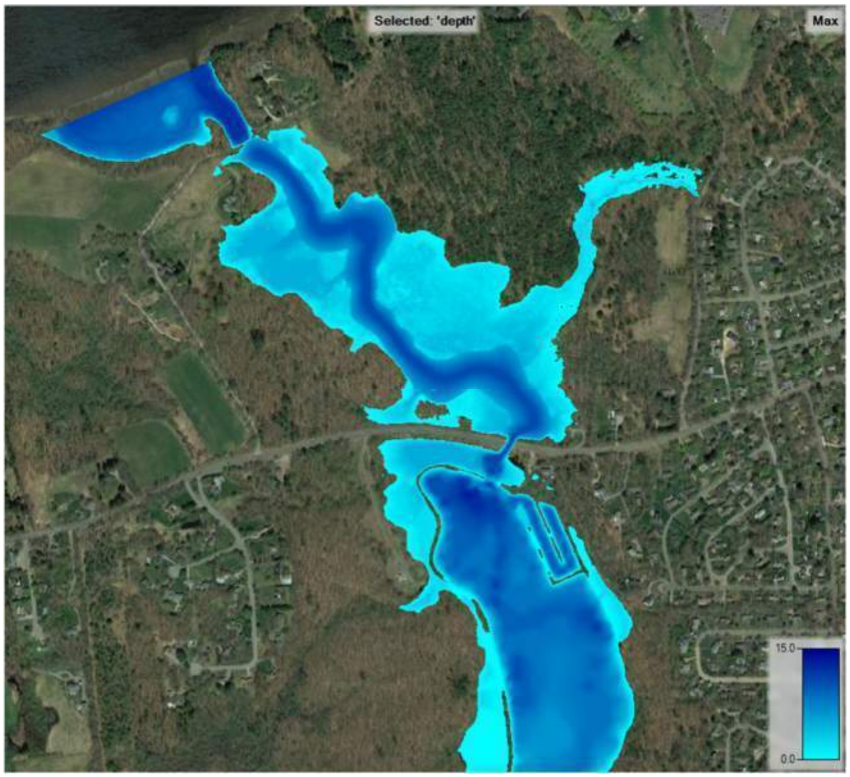


Figure C-14: Two Dimensional HEC-RAS Results for "Run No. 11" 25-Year frequency storm event with Mean Higher High Water (MHHW) plus Sea Level Rise (SLR) downstream boundary conditions.

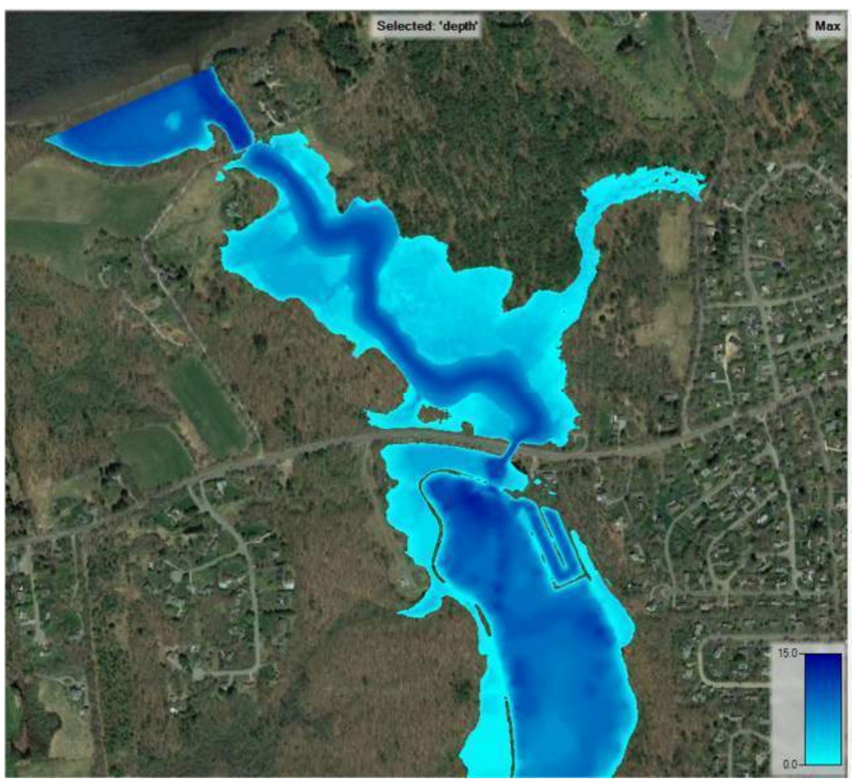


Figure C-15: Two Dimensional HEC-RAS Results for "Run No. 12" 50-Year frequency storm event with Mean Higher High Water (MHHW) plus Sea Level Rise (SLR) downstream boundary conditions.

Figure C-16: Two Dimensional HEC-RAS Results for "Run No. 13" 100-Year frequency storm event with Mean Higher High Water (MHHW) plus Sea Level Rise (SLR) downstream boundary conditions.

Figure C-17: Two Dimensional HEC-RAS Results for "Run No. 14" 500-Year frequency storm event with Mean Higher High Water (MHHW) plus Sea Level Rise (SLR) downstream boundary conditions.

Figure C-18: Two Dimensional HEC-RAS Results for “Run No. 15” Merrimack River FEMA 100-Year Base Flood Elevation (BFE) downstream boundary conditions.

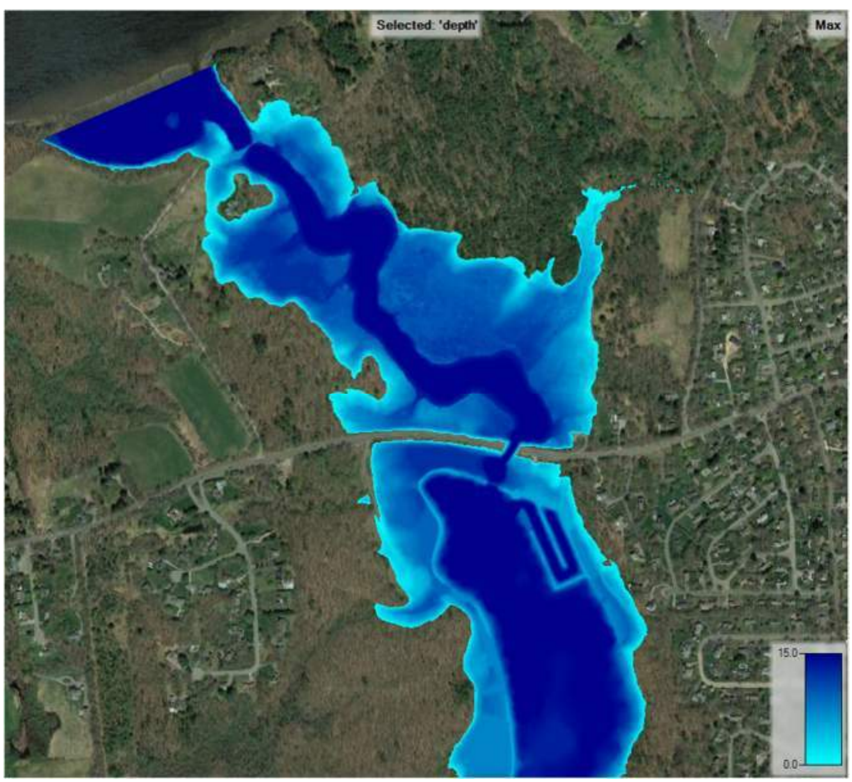


Figure C-19: Two Dimensional HEC-RAS Results for “Run No. 16” Merrimack River FEMA 100-Year Base Flood Elevation (BFE) plus Sea Level Rise (SLR) downstream boundary conditions.

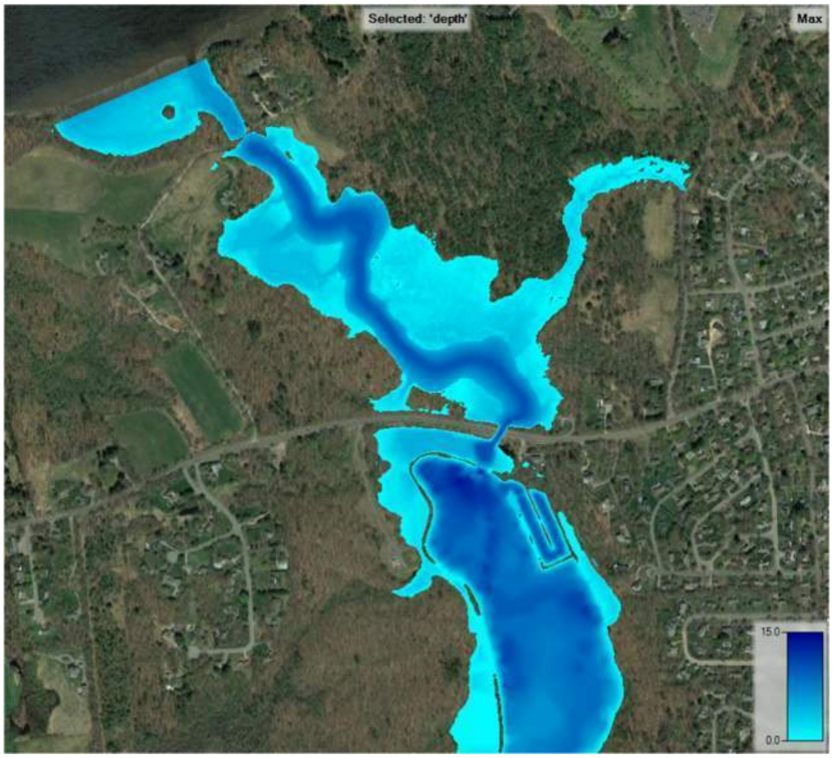


Figure C-20: Two Dimensional HEC-RAS Results for "Run No. 17" 50-Year frequency storm event with Mean Higher High Water (MHHW) downstream boundary conditions – Breach of Lower Artichoke Reservoir Dam.

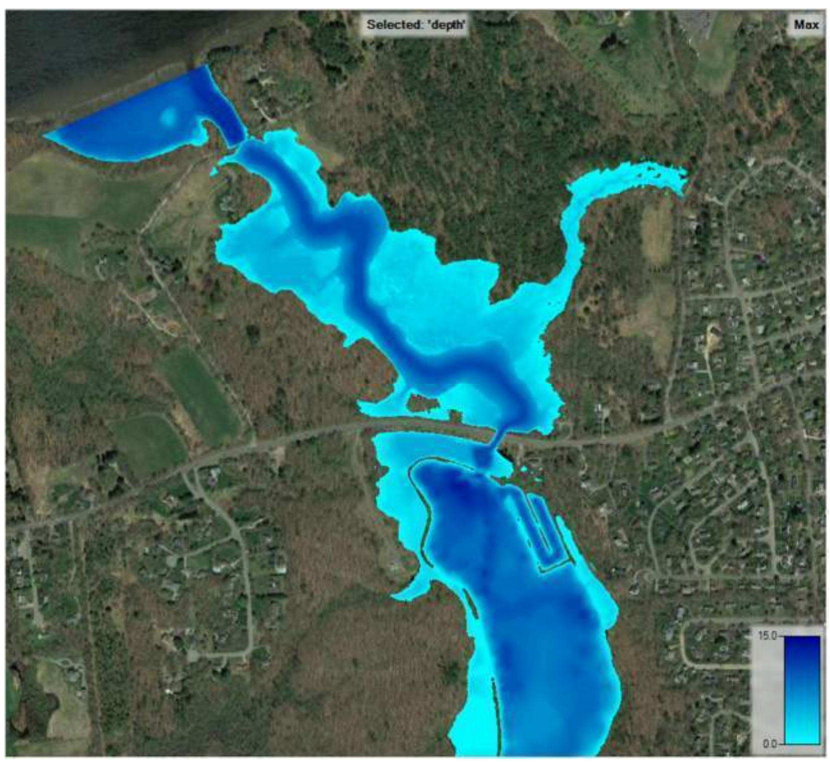


Figure C-21: Two Dimensional HEC-RAS Results for "Run No. 18" 50-Year frequency storm event with Mean Higher High Water (MHHW) plus Sea Level Rise (SLR) downstream boundary conditions – Breach of Lower Artichoke Reservoir Dam.

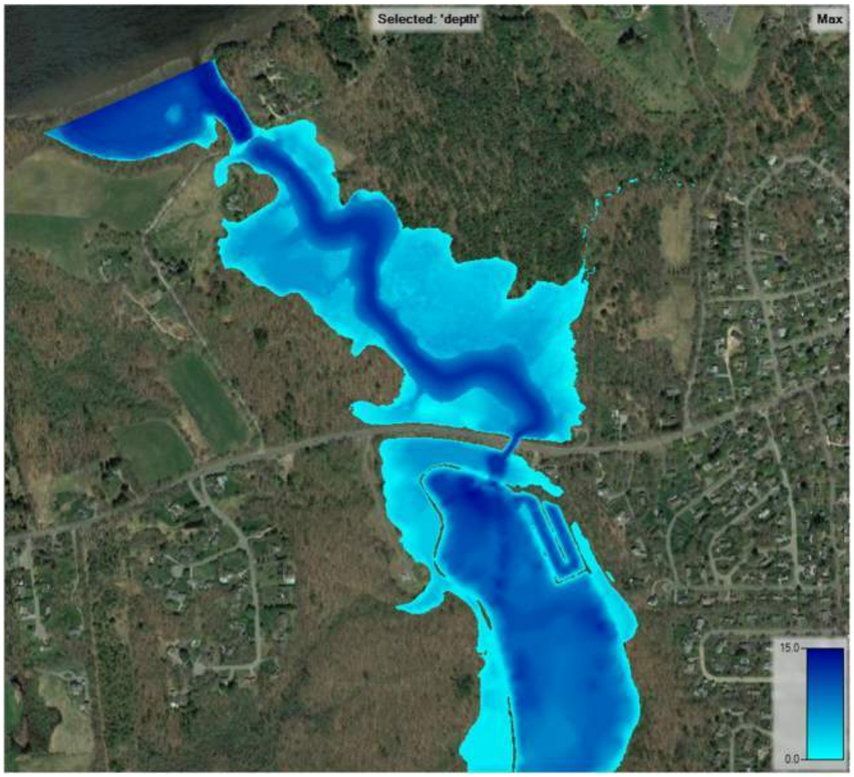
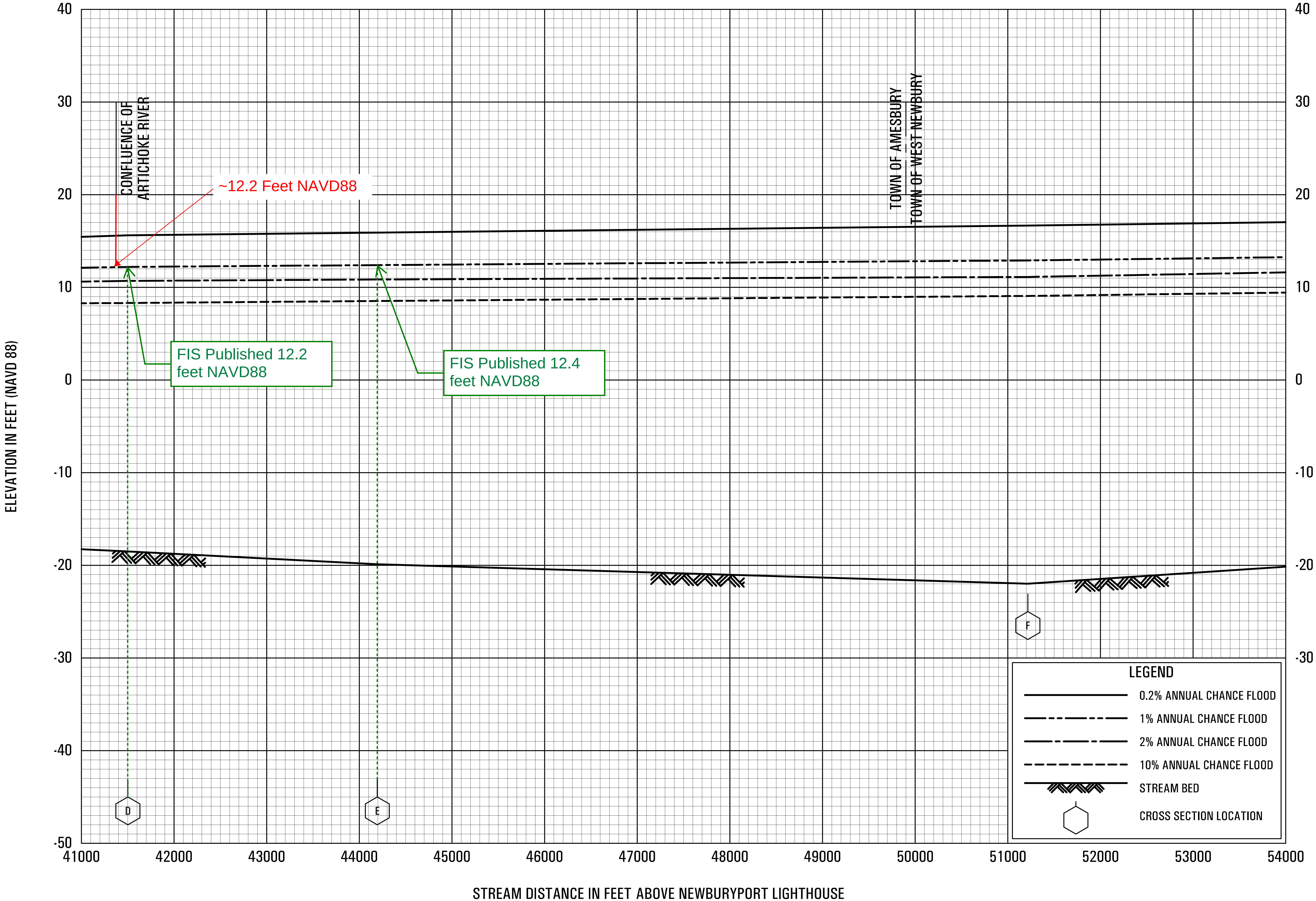


Figure C-22: Two Dimensional HEC-RAS Results for “Run No. 15” Merrimack River FEMA 100-Year Base Flood Elevation (BFE) downstream boundary conditions – Breach of Lower Artichoke Reservoir Dam

APPENDIX D

Pages From Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for Essex County, Massachusetts



FLOOD PROFILES

MERRIMACK RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

ESSEX COUNTY, MA

(ALL JURISDICTIONS)

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
A	28,354	1,041	26,922	4.3	9.8	9.8	9.8	0.0
B	32,208	1,101	27,860	4.1	10.5	10.5	10.5	0.0
C	38,386	1,120	25,350	4.5	11.7	11.7	11.7	0.0
D	41,501	1,830	38,000	3.0	12.2	12.2	12.2	0.0
E	44,194	1,920	37,600	3.1	12.4	12.4	12.4	0.0
F	51,216	880	22,800	5.0	12.9	12.9	12.9	0.0
G	55,176	695	15,700	7.3	13.4	13.4	13.4	0.0
H	60,984	780	16,300	7.1	14.8	14.8	14.9	0.1
I	64,839	1,215	27,600	4.2	16.2	16.2	16.4	0.2
J	70,939	1,015	24,100	4.8	16.8	16.8	17.0	0.2
K	73,999	1,260	26,449	4.4	17.3	17.3	18.3	1.0
L	82,269	772	18,854	6.1	19.1	19.1	20.0	0.9
M	86,389	1,140	27,106	4.2	20.7	20.7	21.6	0.9
N	89,889	*	27,196	4.2	21.1	21.1	22.1	1.0
O	92,229	*	30,465	3.8	21.4	21.4	22.3	0.9
P	93,909	*	16,116	7.1	21.4	21.4	22.3	0.9
Q	97,289	616	16,645	6.9	22.0	22.0	23.0	1.0
R	100,049	*	17,981	6.4	22.7	22.7	23.7	1.0
S	100,294	*	19,426	5.9	22.9	22.9	23.9	1.0
T	100,594	*	15,437	7.5	22.9	22.9	23.9	1.0
U	102,619	*	13,575	8.5	23.1	23.1	24.0	0.9
V	105,599	*	24,161	4.8	24.3	24.3	25.3	1.0
W	108,299	*	16,070	7.2	24.4	24.4	25.3	0.9
X	111,924	*	17,163	6.7	25.1	25.1	26.0	0.9
Y	113,934	570	15,300	7.5	25.2	25.2	26.1	0.9
Z	114,899	570	15,150	7.6	25.8	25.8	26.4	0.6
AA	118,074	*	14,071	8.2	26.5	26.5	27.4	0.9

[1] FEET ABOVE NEWBURYPORT LIGHTHOUSE

* FLOODWAY COINCIDENT WITH CHANNEL BANKS

TABLE 12

FEDERAL EMERGENCY MANAGEMENT AGENCY

ESSEX COUNTY, MA

(ALL JURISDICTIONS)

FLOODWAY DATA

MERRIMACK RIVER

APPENDIX O

Last Saved: 6/21/2021
Plotted On:Jun 24, 2021-2:05pm By: LPT
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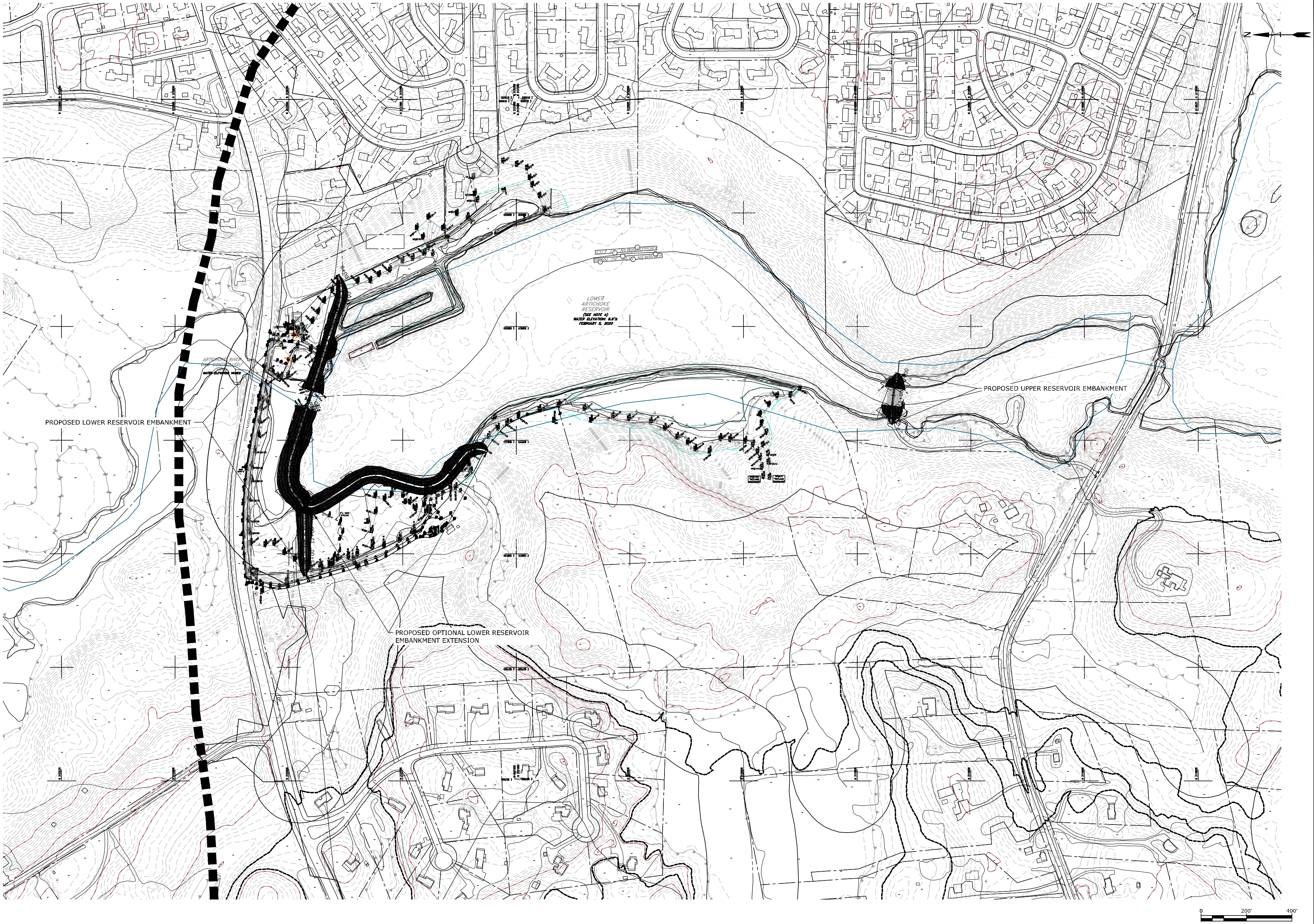

Tighe&Bond

Conceptual Plan Not For Construction

Lower Artichoke Dam Spillway Protection

City of Newburyport Department of Public Services

Newburyport, Massachusetts

MARK	DATE	DESCRIPTION

PROJECT NO:	N5059-001
DATE:	6/2021
FILE:	N5059-001-EMBANKMENT-DESIGN621.dwg
DRAWN BY:	GNM
CHECKED BY:	TJA
APPROVED BY:	PJG

LOWER AND UPPER ARTICHOKE RESERVOIR PLAN

SCALE: AS SHOWN

FIGURE 1

Last Saved: 6/24/2021
Plotted On:Jun 24, 2021-2:09pm By: LPT
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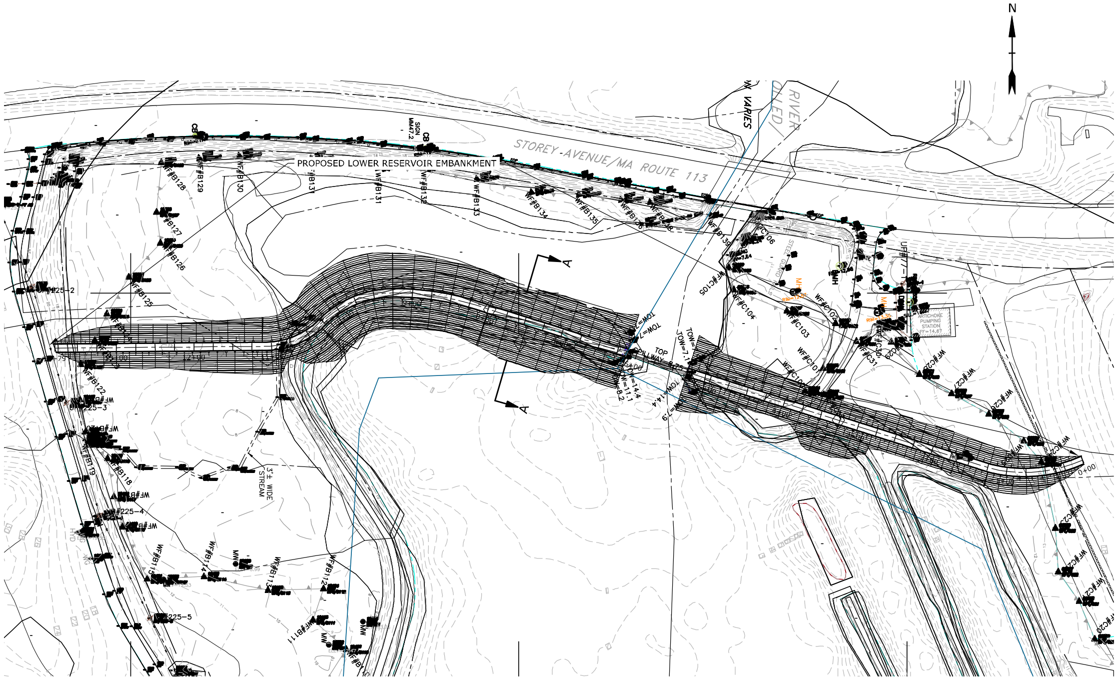
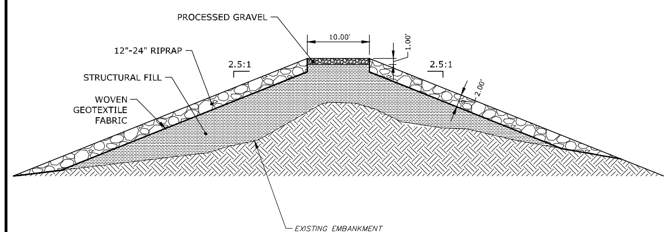
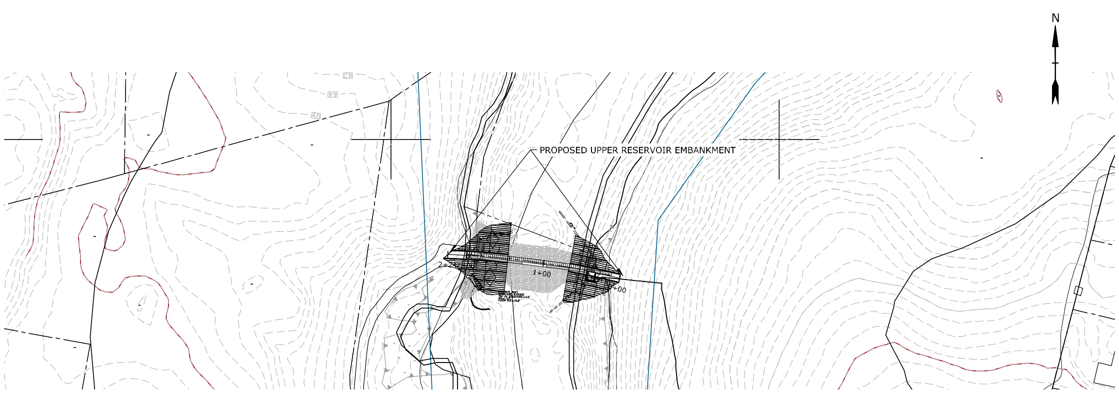


LOWER RESERVOIR - OPTION 1



LOWER ARTICHOKE EMBANKMENT CROSS SECTION A-A
NO SCALE



UPPER RESERVOIR

Tighe&Bond

Conceptual Plan Not For Construction

Lower Artichoke Dam Spillway Protection

City of Newburyport Department of Public Services

Newburyport, Massachusetts

MARK	DATE	DESCRIPTION

PROJECT NO:	N5059-001
DATE:	6/2021
FILE:	N5059-001-EMBANKMENT-DESIGN621.dwg
DRAWN BY:	GNM
CHECKED BY:	TJA
APPROVED BY:	PJG

LOWER AND UPPER ARTICHOKE RESERVOIR EMBANKMENT - 1

SCALE: AS SHOWN

FIGURE 2

Last Saved: 6/24/2021
Plotted On:Jun 24, 2021-2:33pm By: LPT
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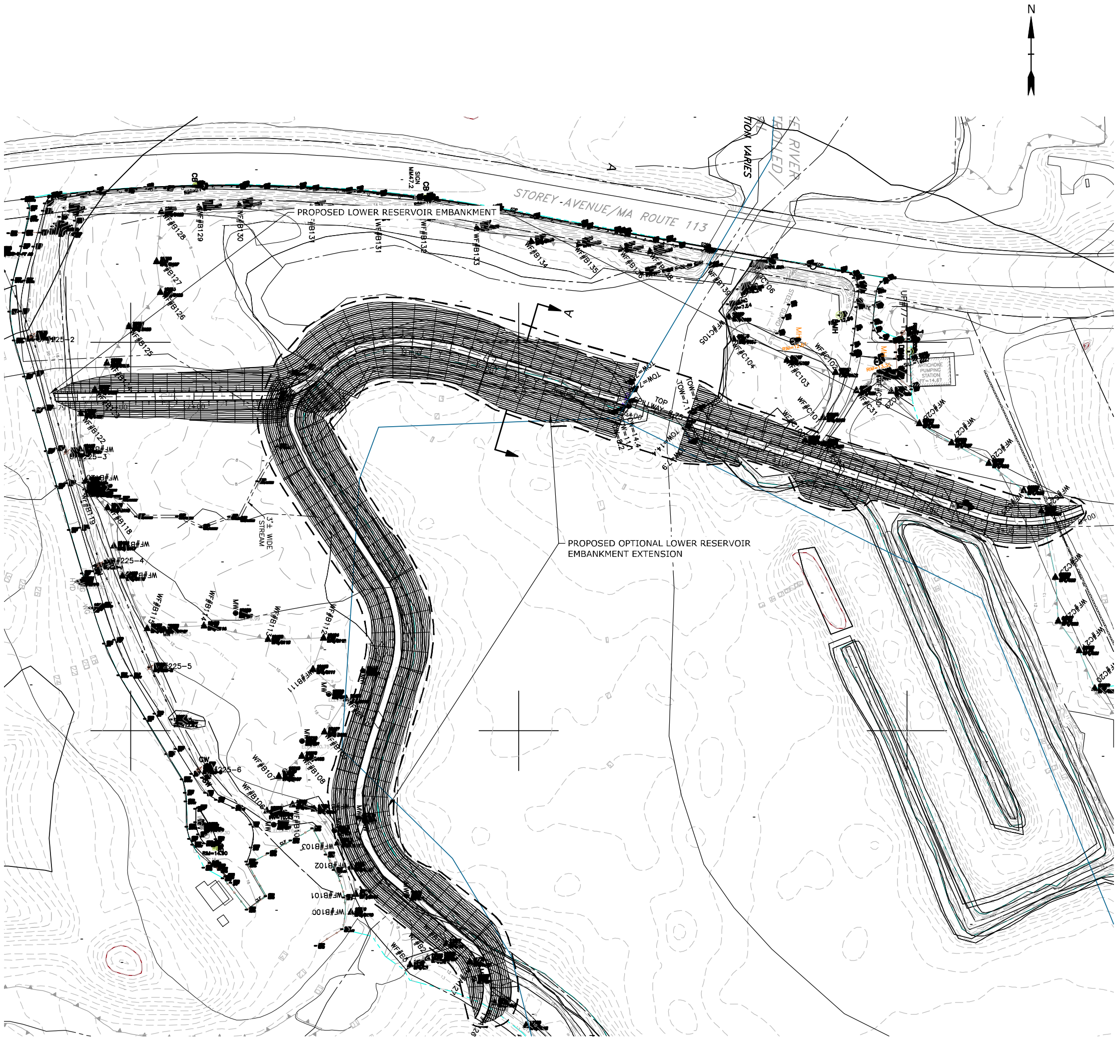
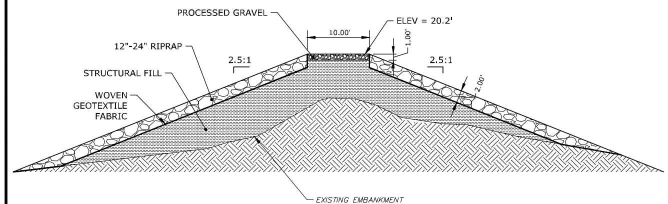


LOWER RESERVOIR - OPTION 2



LOWER ARTICHOKE EMBANKMENT CROSS SECTION A-A
NO SCALE

Tighe&Bond

Conceptual Plan Not For Construction

Lower Artichoke Dam Spillway Protection

City of Newburyport Department of Public Services

Newburyport, Massachusetts

MARK	DATE	DESCRIPTION

PROJECT NO: N5059-001
DATE: 6/2021
FILE: N5059-001-EMBANKMENT-DESIGN621.dwg
DRAWN BY: GNM
CHECKED BY: TJA
APPROVED BY: PJG

LOWER AND UPPER ARTICHOKE RESERVOIR EMBANKMENT - 2

SCALE: AS SHOWN

FIGURE 3

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST [1]

Lower Artichoke Dam Protection

Newburyport, Massachusetts

October 2020

Item	Description	Quantity	Units	Unit Price	Total Price
Base Bid					
1	Mobilization & Demobilization (5% Maximum)	1	LS	$197,925.00	$197,925
2	General Conditions (10%)	1	LS	$593,775.00	$593,775
3	Water Control, Coffer Dam	1	LS	$300,000.00	$300,000
4	Access Road	1	LS	$75,000.00	$75,000
5	Spillway Demolition	260	CY	$300.00	$78,000
6	Spillway Modifcations	130	CY	$1,500.00	$195,000
7	Concrete for Training Walls	615	CY	$1,200.00	$738,000
8	Crest Gate	1	LS	$1,500,000.00	$1,500,000
9	Processed Gravel Borrow	500	CY	$40.00	$20,000
10	Rip Rap Borrow	3,600	CY	$75.00	$270,000
11	Structural Fill Borrow	15,100	CY	$40.00	$604,000
12	Woven Geotextile Fabric	11,900	SY	$15.00	$178,500
				Subtotal =	**$4,750,200**
				30% CONTINGENCY =	**$ 1,426,000**
				Design, Permitting, & Construction Phase Services (15%) =	**$ 713,000**
				OPINION OF PROBABLE CONSTRUCTION COST =	**$ 6,889,200**

[1] This is an engineer’s Opinion of probable Construction Cost (OPCC). Tighe & Bond has no control over the cost or availability of labor, equipment or materials, or over market conditions or the Contractor's method of pricing, and that the estimates of probable construction costs are made on the basis of the Tighe & Bond’s professional judgment and experience. Tighe & Bond makes no guarantee nor warranty, expressed or implied, that the bids or the negotiated cost of the Work will not vary from this estimate of the Probable Construction Cost.

[2] Limits of work extend into adjacent Town and/or private property. Costs do not include land acquistions or easements.

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST [1]

Lower Extension Artichoke Dam Protection

Newburyport, Massachusetts

January 2021

Item	Description	Est. Quantity	Contin.	Quantity	Units	Unit Price	Total Price
Base Bid							
9	Processed Gravel Borrow	343	10%	400	CY	$40.00	$16,000
10	Rip Rap Borrow	2,261	10%	2,500	CY	$75.00	$187,500
11	Structural Fill Borrow	9,558	10%	10,500	CY	$40.00	$420,000
12	Woven Geotextile Fabric	7,503	10%	8,300	SY	$15.00	$124,500
						Subtotal =	**$748,000**
						30% CONTINGENCY =	**$ 225,000**
						Design, Permitting, & Construction Phase Services (15%) =	**$ 113,000**
						OPINION OF PROBABLE CONSTRUCTION COST =	**$ 1,086,000**

[1] This is an engineer's Opinion of probable Construction Cost (OPCC). Tighe & Bond has no control over the cost or availability of labor, equipment or materials, or over market conditions or the Contractor's method of pricing, and that the estimates of probable construction costs are made on the basis of the Tighe & Bond's professional judgment and experience. Tighe & Bond makes no guarantee nor warranty, expressed or implied, that the bids or the negotiated cost of the Work will not vary from this estimate of the Probable Construction Cost.

[2] Limits of work extend into adjacent Town and/or private property. Costs do not include land acquistions or easements.

Tighe&Bond

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST [1]

Upper Artichoke Dam Protection

Newburyport, Massachusetts

October 2020

Item	Description	Quantity	Units	Unit Price	Total Price
Base Bid					
1	Mobilization & Demobilization (5% Maximum)	1	LS	$125,975	$125,975
2	General Conditions (15%)	1	LS	$377,925	$377,925
3	Water Control, Coffer Dam	1	LS	$300,000	$300,000
4	Spillway Demolition	260	CY	$300	$78,000
5	Spillway Modifcations	130	CY	$1,500	$195,000
6	Concrete for Training Walls	280	CY	$1,200	$336,000
7	Crest Gate	1	LS	$1,500,000	$1,500,000
8	Processed Gravel Borrow	100	CY	$40	$4,000
9	Rip Rap Borrow	400	CY	$75	$30,000
10	Structural Fill Borrow	1,500	CY	$40	$60,000
11	Woven Geotextile Fabric	1,100	SY	$15	$16,500
				Subtotal =	**$3,023,400**
				30% CONTINGENCY =	**$ 908,000**
				Design, Permitting, & Construction Phase Services (15%) =	**$ 454,000**
				OPINION OF PROBABLE CONSTRUCTION COST =	**$ 4,385,400**

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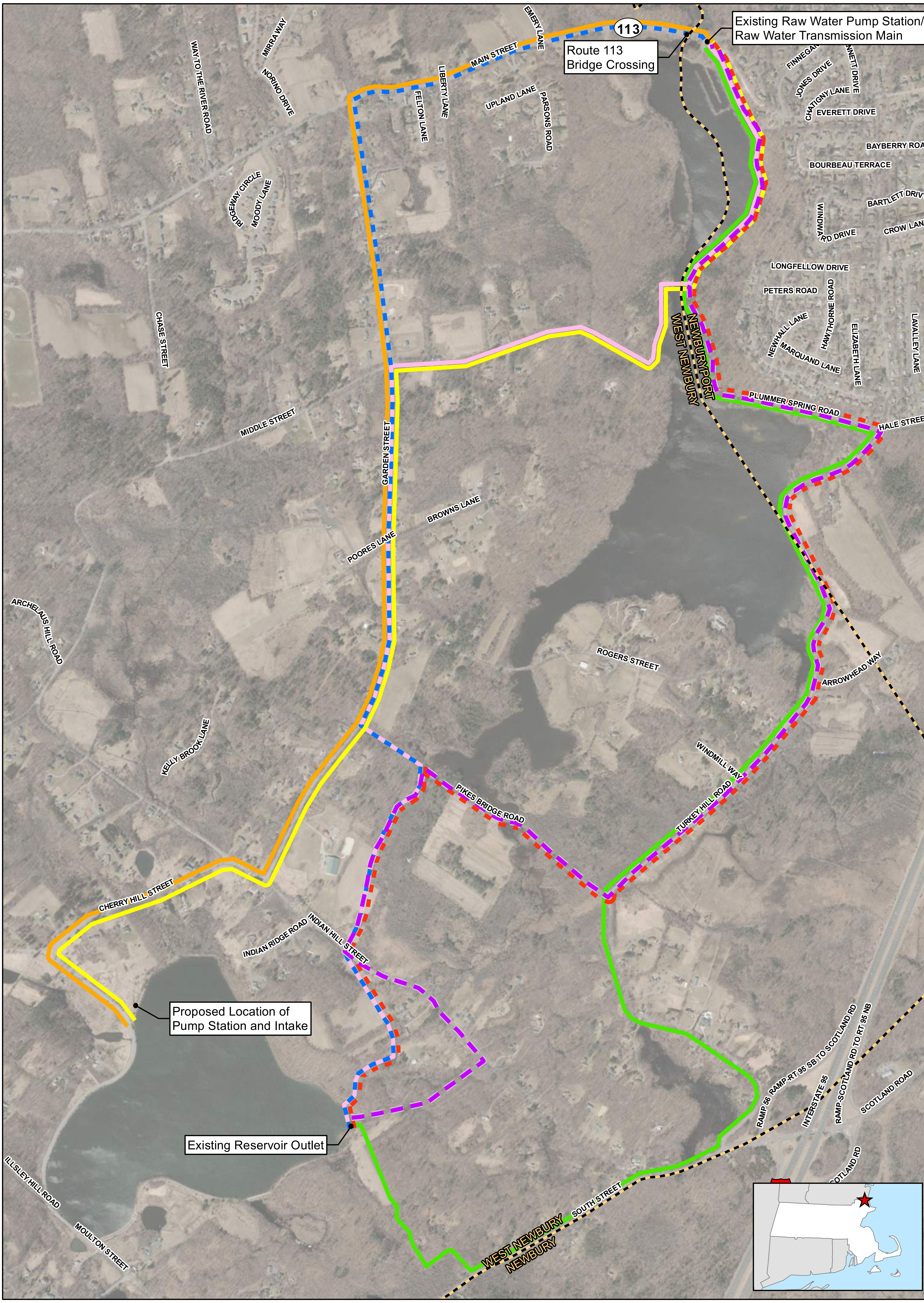
[2] Limits of work extend into adjacent Town and/or private property. Costs do not include land acquistions or easements.

APPENDIX P



LEGEND

- Alternative 1 - 23,100 LF
- Alternative 2 - 20,600 LF
- Alternative 2a - 21,821 LF
- Alternative 3 - 16,800 LF
- Alternative 4 - 16,650 LF
- Alternative 5 - 17,350 LF
- Alternative 6 - 17,500 LF
- Town Boundary

1:12,000

0 500 1,000

Feet

Tighe&Bond

1. Based on MassGIS Color Orthophotography (2019)

FIGURE 1
SITE OVERVIEW

Draft Raw Water Line
Options from Indian Hill
Newburyport, Massachusetts

January 2021

V:\Projects\N\N5059\NewburyportRawWaterTransmissionAlts\RawWaterLineOptions_NewburyportMA_11x17_V2.mxd [Exported By: kjw, 1/28/2021, 10:33:46 AM]

n-5059

Opinion of Probable Construction Costs

Alternative	Pipeline Cost	Pump Station and Intakes	15% General Conditions	25% Contingency	Total Construction Cost	Engineering Cost	Total OPCC
Alternative 1 - Cross Country/ South Street/ Turkey Hill Road	$6,348,400	$2,925,000	$1,391,010	$2,666,103	**$13,330,513**	$2,666,103	**$15,997,000**
Alternative 2 – Cross Country/ Pikes Br Rd/ Turkey Hill Rd	$5,642,142	$2,925,000	$1,285,071	$2,463,053	**$12,315,266**	$2,463,053	**$14,778,000**
Alternative 2A – Cross Country/ Pikes Br Rd/ Turkey Hill Rd	$7,511,240	$330,000	$1,185,186	$2,271,607	**$11,358,033**	$2,271,607	**$13,630,000**
Alternative 3 - Cross Country/ Pikes Br Rd/ Garden Rd/ Middle St	$4,805,877	$2,925,000	$1,159,632	$2,222,627	**$11,113,135**	$2,222,627	**$13,336,000**
Alternative 4 - Cross Country/ Pikes Br Rd/ Garden St/Rt 113	$5,021,366	$2,745,000	$1,164,955	$2,232,830	**$11,164,151**	$2,232,830	**$13,397,000**
Alternative 5 - Moulton St/ Cherry Hill St/ Garden St/ Rt 113	$5,303,500	$2,795,000	$1,214,775	$2,328,319	**$11,641,594**	$2,328,319	**$13,970,000**
Alternative 6 - Moulton St/ Cherry Hill St/ Garden St/ Middles St/ Cross Country	$5,008,080	$3,025,000	$1,204,962	$2,309,511	**$11,547,553**	$2,309,511	**$13,857,000**

Tighe&Bond

RAW WATER TRANSMISSION MAIN ALTERNATIVES ANALYSIS - ALTERNATIVE 1
NEWBURYPORT, MASSACHUSETTS

OPINION OF PROBABLE CONSTRUCTION COST

CITY OF NEWBURYPORT

ITEM	DESCRIPTION	UNITS	QTY	UNIT PRICE	SUB TOTAL	TOTAL
1.	**Pipeline**					**$9,273,400**
	16" Water Main - Cross Country	LF	7,100	$240	$1,704,000	$1,704,000
	16" Water Main - Within Roadway - Paved	LF	16,000	$280	$4,480,000	$4,480,000
	Clearing and Grubbing for Water Main	SF	243,800	$0.50	$121,900	$121,900
	Clearing and Grubbing for Pump Station	SF	22,500	$0.50	$11,250	$11,250
	Gravel Access Road for Upper Artichoke Dam	SY	2,083	$15.00	$31,250	$31,250
	Raw Water Pump Station	LS	1	$2,300,000	$2,300,000	$2,300,000
	Intake Structure - Upper Artichoke & Indian Hill	LS	2	$180,000	$360,000	$360,000
	Intake Airburst System - Indian Hill	LS	1	$250,000	$250,000	$250,000
	Connection to Existing Raw Water Pump Station	LS	1	$15,000	$15,000	$15,000
					SUBTOTAL	**$9,273,400**
2	**General Conditions - 15%**					**$1,391,010**
					CONSTRUCTION - SUBTOTAL	**$10,664,410**
3	**Contingency - 25%**					**$2,666,103**
					CONSTRUCTION - SUBTOTAL	**$13,330,513**
4	**Engineering - 20%**					**$2,666,103**
					TOTAL	**$15,997,000**

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RAW WATER TRANSMISSION MAIN ALTERNATIVES ANALYSIS - ALTERNATIVE 2
NEWBURYPORT, MASSACHUSETTS
OPINION OF PROBABLE CONSTRUCTION COST
CITY OF NEWBURYPORT

ITEM	DESCRIPTION	UNITS	QTY	UNIT PRICE	SUB TOTAL	TOTAL
1.	**Pipeline**					**$8,567,142**
	16" Water Main - Cross Country	LF	9,100	$240	$2,184,000	$2,184,000
	16" Water Main - Within Roadway	LF	11,500	$280	$3,220,000	$3,220,000
	Clearing and Grubbing - Water Main	SF	391,283	$0.50	$195,642	$195,642
	Clearing and Grubbing - Pump Station	SF	22,500	$0.50	$11,250	$11,250
	Gravel Access Road for Upper Artichoke Dam	SY	2,083	$15.00	$31,250	$31,250
	Raw Water Pump Station	LS	1	$2,300,000	$2,300,000	$2,300,000
	Intake Structure - Upper Artichoke & Indian Hill	LS	2	$180,000	$360,000	$360,000
	Intake Airburst System - Indian Hill	LS	1	$250,000	$250,000	$250,000
	Connection to Existing Raw Water Pump Station	LS	1	$15,000	$15,000	$15,000
					SUBTOTAL	**$8,567,142**
2	**General Conditions - 15%**					**$1,285,071**
					CONSTRUCTION - SUBTOTAL	**$9,852,213**
3	**Contingency - 25%**					**$2,463,053**
					CONSTRUCTION - SUBTOTAL	**$12,315,266**
4	**Engineering - 20%**					**$2,463,053**
					TOTAL	**$14,778,000**

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RAW WATER TRANSMISSION MAIN ALTERNATIVES ANALYSIS - ALTERNATIVE 2A
NEWBURYPORT, MASSACHUSETTS
OPINION OF PROBABLE CONSTRUCTION COST
CITY OF NEWBURYPORT

ITEM	DESCRIPTION	UNITS	QTY	UNIT PRICE	SUB TOTAL	TOTAL
1.	**Pipeline**					**$7,901,240**
	24" Water Main HDD - Road to Dam at Indian Hill	LS	1	$951,500	$951,500	$951,500
	36" Water Main - Within Roadway	LF	13,850	$345	$4,778,250	$4,778,250
	20" Water Main - Within Roadway	LF	6,300	$250	$1,575,050	$1,575,050
	Clearing and Grubbing - Water Main	SF	329,640	$0.50	$164,820	$164,820
	Excavation	CY	1,037	$10.00	$10,370	$10,370
	16" - HDE	LF	0	$750.00	$0	$0
	Gravel Access Road for Upper Artichoke Dam	SY	2,083	$15.00	$31,250	$31,250
	Intake Structure - Upper Artichoke	LS	1	$180,000	$180,000	$180,000
	Connection to Existing Intake Structure Outfall Piping	LS	1	$150,000	$150,000	$150,000
	Connection to Existing Raw Water Pump Station	LS	1	$54,000.00	$60,000	$60,000
					SUBTOTAL	**$7,901,240**
2	**General Conditions - 15%**					**$1,185,186**
					CONSTRUCTION - SUBTOTAL	**$9,086,426**
3	**Contingency - 25%**					**$2,271,607**
					CONSTRUCTION - SUBTOTAL	**$11,358,033**
4	**Engineering - 20%**					**$2,271,607**
					TOTAL	**$13,630,000**

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RAW WATER TRANSMISSION MAIN ALTERNATIVES ANALYSIS - ALTERNATIVE 3
NEWBURYPORT, MASSACHUSETTS
OPINION OF PROBABLE CONSTRUCTION COST
CITY OF NEWBURYPORT

ITEM	DESCRIPTION	UNITS	QTY	UNIT PRICE	SUB TOTAL	TOTAL
1.	**Pipeline**					**$7,730,877**
	16" Water Main - Cross Country	LF	7,800	$240	$1,872,000	$1,872,000
	16" Water Main - Within Roadway - Paved	LF	7,900	$280	$2,212,000	$2,212,000
	16" Water Main - Within Roadway - Gravel	LF	1,100	$240	$264,000	$264,000
	16" Water Main - Horizontal Directional Drilling	LF	330	$750	$247,500	$247,500
	Clearing and Grubbing - Water Main	SF	335,754	$0.50	$167,877	$167,877
	Clearing and Grubbing - Pump Staion	SF	22,500	$0.50	$11,250	$11,250
	Gravel Access Road for Upper Artichoke Dam	SY	2,083	$15.00	$31,250	$31,250
	Raw Water Pump Station	LS	1	$2,300,000	$2,300,000	$2,300,000
	Intake Structure - Upper Artichoke & Indian Hill	LS	2	$180,000	$360,000	$360,000
	Intake Airburst System - Indian Hill	LS	1	$250,000	$250,000	$250,000
	Connection to Existing Raw Water Pump Station	LS	1	$15,000	$15,000	$15,000
					SUBTOTAL	**$7,730,877**
2	**General Conditions - 15%**					**$1,159,632**
					CONSTRUCTION - SUBTOTAL	**$8,890,508**
3	**Contingency - 25%**					**$2,222,627**
					CONSTRUCTION - SUBTOTAL	**$11,113,135**
4	**Engineering - 20%**					**$2,222,627**
					TOTAL	**$13,336,000**

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RAW WATER TRANSMISSION MAIN ALTERNATIVES ANALYSIS - ALTERNATIVE 4
NEWBURYPORT, MASSACHUSETTS

OPINION OF PROBABLE CONSTRUCTION COST

CITY OF NEWBURYPORT

ITEM	DESCRIPTION	UNITS	QTY	UNIT PRICE	SUB TOTAL	TOTAL
1.	**Pipeline**					**$7,766,366**
	16" Water Main - Cross Country	LF	4,600	$240	$1,104,000	$1,104,000
	16" Water Main - Within Roadway - Paved	LF	11,900	$280	$3,332,000	$3,332,000
	16" Water Main - Installed under MassDOT Bridge	LF	150	$3,250	$487,500	$487,500
	Clearing and Grubbing - Water Main	SF	173,231	$0.50	$86,616	$86,616
	Clearing and Grubbing - Pump Station	SF	22,500	$0.50	$11,250	$11,250
	Raw Water Pump Station	LS	1	$2,300,000	$2,300,000	$2,300,000
	Intake Structure - Indian Hill	LS	1	$180,000	$180,000	$180,000
	Intake Airburst System - Indian Hill	LS	1	$250,000	$250,000	$250,000
	Connection to Existing Raw Water Pump Station	LS	1	$15,000	$15,000	$15,000
					SUBTOTAL	**$7,766,366**
2	**General Conditions - 15%**					**$1,164,955**
					CONSTRUCTION - SUBTOTAL	**$8,931,320**
3	**Contingency - 25%**					**$2,232,830**
					CONSTRUCTION - SUBTOTAL	**$11,164,151**
4	**Engineering - 20%**					**$2,232,830**
					TOTAL	**$13,397,000**

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RAW WATER TRANSMISSION MAIN ALTERNATIVES ANALYSIS - ALTERNATIVE 5
NEWBURYPORT, MASSACHUSETTS
OPINION OF PROBABLE CONSTRUCTION COST
CITY OF NEWBURYPORT

ITEM	DESCRIPTION	UNITS	QTY	UNIT PRICE	SUB TOTAL	TOTAL
1.	**Pipeline**					**$8,098,500**
	16" Water Main - Within Roadway - Paved	LF	17200	$280	$4,816,000	$4,816,000
	16" Water Main - Installed under MassDOT Bridge	LF	150	$3,250	$487,500	$487,500
	Raw Water Pump Station	LS	1	$2,300,000	$2,300,000	$2,300,000
	Intake Structure - Indian Hill Reservoir	EA	1	$180,000	$180,000	$180,000
	Intake Airburst System - Indian Hill Reservoir	EA	1	$250,000	$250,000	$250,000
	Connection to Existing Raw Water Pump Station	LS	1	$15,000	$15,000	$15,000
	Connection to Existing Intake Structure Outfall Piping	LS	1	$50,000	$50,000	$50,000
					SUBTOTAL	**$8,098,500**
2	**General Conditions - 15%**					**$1,214,775**
					CONSTRUCTION - SUBTOTAL	**$9,313,275**
3	**Contingency - 25%**					**$2,328,319**
					CONSTRUCTION - SUBTOTAL	**$11,641,594**
4	**Engineering - 20%**					**$2,328,319**
					TOTAL	**$13,970,000**

This is an engineer's Opinion of probable Construction Cost (OPCC). Tighe & Bond has no control over the cost or availability of labor, equipment or materials, or over market conditions or the Contractor's method of pricing, and that the Opinion of Probable Construction Costs are made on the basis of the Tighe & Bond's professional judgment and experience. Tighe & Bond makes no guarantee nor warranty, expressed or implied, that the bids or the negotiated cost of the Work will not vary from this Opinion of the Probable Construction Cost.

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RAW WATER TRANSMISSION MAIN ALTERNATIVES ANALYSIS - ALTERNATIVE 6
NEWBURYPORT, MASSACHUSETTS

OPINION OF PROBABLE CONSTRUCTION COST

CITY OF NEWBURYPORT

ITEM	DESCRIPTION	UNITS	QTY	UNIT PRICE	SUB TOTAL	TOTAL
1.	**Pipeline**					**$8,033,080**
	16" Water Main - Cross Country	LF	2870	$240	$688,800	$688,800
	16" Water Main - Within Roadway - Paved	LF	13200	$280	$3,696,000	$3,696,000
	16" Water Main - Within Roadway - Gravel	LF	1,100	$240	$264,000	$264,000
	16" Water Main - Horizontal Directional Drilling	LF	330	$750	$247,500	$247,500
	Clearing and Grubbing - Water Main	SF	161060	$0.50	$80,530	$80,530
	Gravel Access Road for Upper Artichoke Dam	SY	2,083	$15.00	$31,250	$31,250
	Raw Water Pump Station	LS	1	$2,300,000	$2,300,000	$2,300,000
	Intake Structure - Indian Hill and Upper Artichoke	EA	2	$250,000	$500,000	$500,000
	Intake Airburst System - Indian Hill	EA	1	$210,000	$210,000	$210,000
	Connection to Existing Raw Water Pump Station	LS	1	$15,000	$15,000	$15,000
					SUBTOTAL	**$8,033,080**
2	**General Conditions - 15%**					**$1,204,962**
					CONSTRUCTION - SUBTOTAL	**$9,238,042**
3	**Contingency - 25%**					**$2,309,511**
					CONSTRUCTION - SUBTOTAL	**$11,547,553**
4	**Engineering - 20%**					**$2,309,511**
					TOTAL	**$13,857,000**

This is an engineer's Opinion of probable Construction Cost (OPCC). Tighe & Bond has no control over the cost or availability of labor, equipment or materials, or over market conditions or the Contractor's method of pricing, and that the Opinion of Probable Construction Costs are made on the basis of the Tighe & Bond's professional judgment and experience. Tighe & Bond makes no guarantee nor warranty, expressed or implied, that the bids or the negotiated cost of the Work will not vary from this Opinion of the Probable Construction Cost.

APPENDIX Q

Upstream Public Water Supply Systems Receiving Water from Merrimack River

TO: Jon-Eric White, PE, City Engineer (City of Newburyport)

FROM: Thomas LeCourt, Megan Carpenter (Tighe and Bond)

COPY: Tracy Adamski (Tighe and Bond)

DATE: November 6, 2020

There are several communities upstream of the Newburyport who draw public water supply directly from the Merrimack River including Lowell, Tewksbury, Lawrence, and Methuen in Massachusetts and the Pennichuck Corporation in New Hampshire. This memo summarizes the public water supply treatment for upstream communities that use the Merrimack River for drinking water supply.

Lowell

Lowell Regional Water Utility (LRWU) is responsible for providing public drinking water to approximately 135,000 customers in the communities of Lowell, Dracut, Tewksbury, Tyngsboro, and Chelmsford. The sole source of water supply is the Merrimack River. The intake station is located on the riverbank north of the city and water is pumped half a mile to the water treatment plant. In 2019, LRWU reported treating more than 4.1 billion gallons (BG).

Treatment at the Lowell Water Treatment Facility includes the addition of chlorine, alum, and sodium hydroxide. Flow is split into two separated trains where flocculation and settling takes place, followed by filtration. One train includes three sand filters, the other dual media and GAC filters in series. Flow is recombined and enters the clearwell, where chlorine and sodium hydroxide are added as finishing chemicals. Sedimentation residuals from LRWU's are directed to one of three residual handling lagoons at the treatment facility. Supernatant from the lagoons discharges into the Merrimack River. The outfall is sampled weekly and LRWU maintains a NPDES discharge permit for the lagoons.

Tewksbury

Tewksbury Water Department provides public drinking water to over 10,000 residential and commercial customers in Tewksbury, MA. The treatment plant and intake station are located directly alongside the Merrimack River. The treatment facility has 7 million gallons per day (MGD) treatment capacity. Tewksbury has interconnections with other water systems.

The Tewksbury water treatment plant uses conventional treatment, including screening, disinfection with chlorine dioxide and sodium hypochlorite, coagulation by alum, and dual-media filtration. Finishing treatment includes the addition of sodium hydroxide for pH adjustment, fluoride to prevent tooth decay, and zinc ortho phosphate to prevent pipe corrosion and reduce dissolution of lead and copper. Tewksbury mixes their raw sludge with diatomaceous earth and transports the residuals to farms across Massachusetts to be used as fertilizer in agricultural processes.

Tewksbury also takes an active role in protecting their drinking water source. The Town has an emergency management committee which works with upstream communities to prepare for emergencies and coordinates activities with Massachusetts Emergency Management Agency (MEMA) and address a variety of source protection issues.

Lawrence

The City of Lawrence, MA has a relatively new Water Treatment Facility which was built in 2006 along the Merrimack River. The facility treats an average of 6 MGD and over 2 BG per year. Treatment includes coagulation, flocculation, sedimentation, filtration, fluoridation, UV disinfection, and chlorine disinfection. Lawrence maintains interconnections with Andover, Methuen, and North Andover. The City actively works with upstream communities to prepare for emergencies and to address a variety of source protection issues.

Methuen

The City of Methuen provides an average of 4.5 MGD, and approximately 1.7 BG per year to over 18,000 customers. Conventional treatment, including pre-disinfection via chlorine dioxide, alum coagulation, flocculation, and sedimentation. Sodium hydroxide is added for pH adjustment, sodium hypochlorite for disinfection, and blended phosphate as a corrosion inhibitor.

Pennichuck Corporation

Pennichuck Water Works provides potable water to a total population of approximately 110,000 people in five southern New Hampshire communities including Nashua, Merrimack, Amherst, Milford, and Hollis. The primary water supply consists of about 195 acres of water in a series of chain ponds that includes Harris Pond, Bowers Pond, and Holts Pond. After flowing through the series of chain ponds, Pennichuck Brook ultimately joins the Merrimack River. Pennichuck draws its water supply upstream of the Merrimack River.

Treatment for surface water includes up-flow clarification using ferric chloride and a non-ionic polymer; granular activated carbon (GAC) filtration; pH adjustment using sodium hydroxide; zinc orthophosphate for corrosion inhibition; polyphosphate as a sequestering agent; and liquid chlorine for disinfection. Pennichuck has interconnections with surrounding water systems.

Pennichuck actively participates in the restoration of watersheds, including the implementation of the Pennichuck Brook Watershed Restoration Plan. The plan address reduction of pollutant discharges, specifically phosphorus loading, which enters Pennichuck Brook, and ultimately the Merrimack River.

Conclusion

Public water treatment for communities upstream of Newburyport, along the Merrimack River consists primarily of conventional treatment methods, including coagulation and flocculation, sedimentation, filtration, and chlorine or UV disinfection. Some systems add additional chemicals for fluoridation, pH control, and corrosion inhibition as shown in **Table 1**. The evaluated systems of Lowell, Tewksbury, Lawrence, Methuen, and Pennichuck Corporation all actively participated in watershed protection activities and emergency planning. It is important to note that the intakes for these systems are above the tidal influence and therefore do not experience brackish conditions.

TABLE 1

Treatment Processes for Public Drinking Water Systems Along the Merrimack River

System	Coagulation/ Flocculation	Sedimentation	Filtration	Disinfection	Corrosion Control	Finishing Chemicals
Lowell	Alum	Yes	Sand Dual media GAC	Chlorine, UV	No	Sodium hydroxide, Fluoride
Tewksbury	Alum	Yes	Dual media	Chlorine Dioxide, Sodium Hypochlorite	Zinc Ortho-phosphate	Sodium hydroxide, Fluoride
Lawrence	Yes	Yes	Yes	UV, Chlorine	No	Fluoride
Methuen	Alum	Yes	No	Chlorine-dioxide (pre-disinfection), Sodium hypochlorite	Blended phosphate	Sodium hydroxide
Pennichuck Corporation	Ferric chloride, Non-ionic polymer	Up-flow clarification	GAC	Sodium hypochlorite	Zinc Ortho-phosphate	Sodium hydroxide, Poly-phosphate

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