A Regulatory, Environmental, and Economic Analysis of Water Supply Protection in Auburn, Maine

FOR THE CITY OF AUBURN, ME

FB Environmental Associates
Horsley Witten Group
The University of Maine

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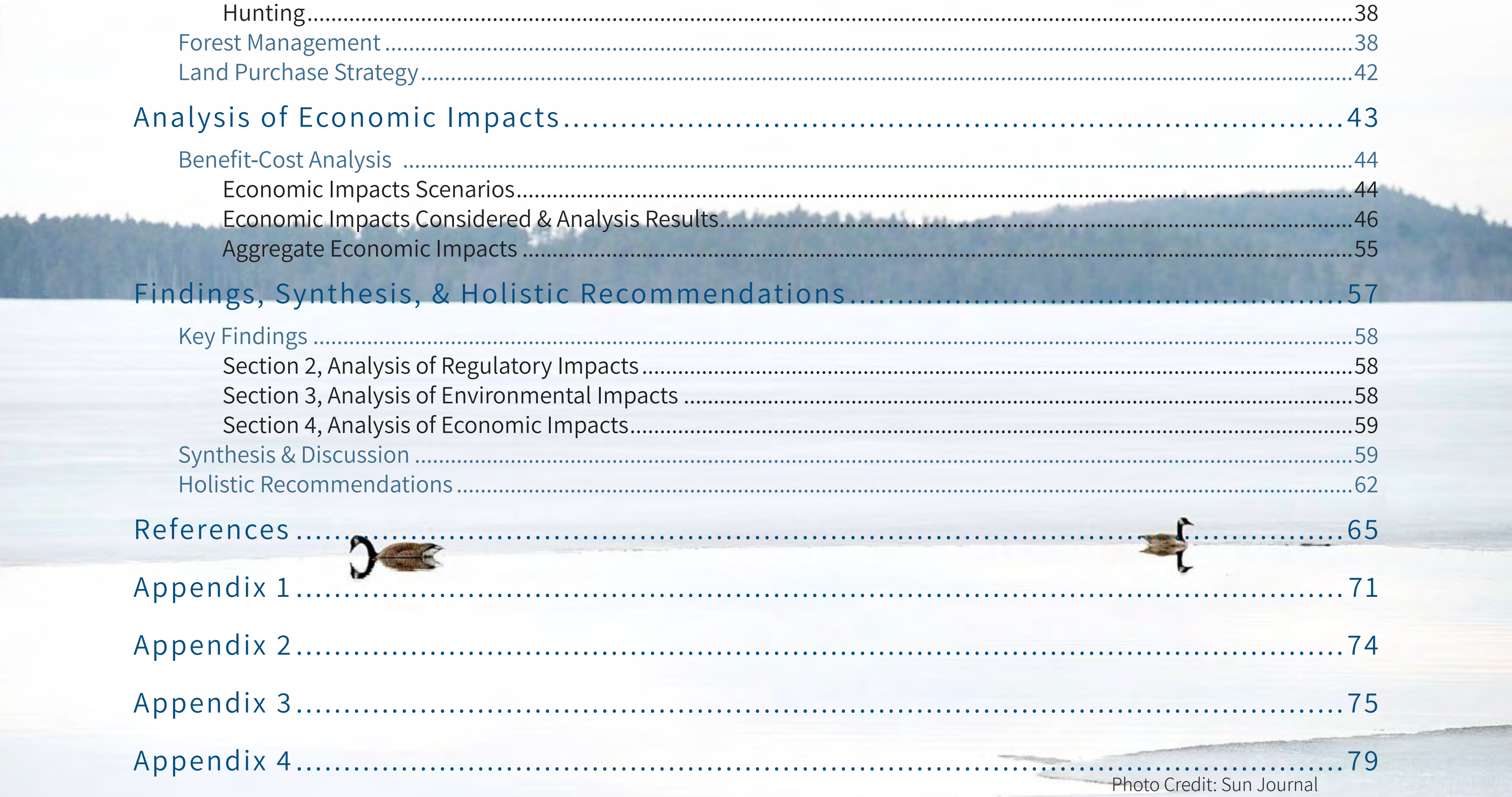

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Executive Summary

Lake Auburn is the only public drinking water supply for the Maine cities of Auburn and Lewiston. In recent years, signs of declining water quality have given rise to public calls for actions that would upend the status quo of the last several decades. Some have argued that the authorities in charge of ensuring a clean water supply from Lake Auburn should protect more of the watershed that contributes to the lake. Others have called for the City of Auburn, the Auburn Water District, or other authorities to revise the regulatory framework that protects the lake from encroaching activities that could contaminate it, while still others have proposed proactively building a water filtration plant to treat water of more variable quality. These suggested actions, while not inherently conflicting, have not yet been comprehensively examined for the potential benefits to Lake Auburn's water quality, nor have the regulatory or economic impacts been adequately considered.

The City of Auburn commissioned the present study to address this gap in understanding about Lake Auburn's present state compared to a range of future scenarios. In 2021, the City hired the interdisciplinary consultant team of FB Environmental Associates, Horsley Witten Group, and the University of Maine to 1) carry out a thorough review of existing conditions, standards, regulations, and practices in Lake Auburn and its watershed, 2) quantify to the greatest extent possible the regulatory, environmental, and economic impacts of the current status quo and future scenarios, and 3) evaluate and recommend potential ways forward that maximizes the benefits and minimizes the costs of regulatory, environmental, and economic impacts to Lake Auburn, its watershed, and the surrounding communities.

This report follows three lines of inquiry examining the key aspects of Lake Auburn as a water supply – its regulations, its environment, and its economics. These lines of inquiry are treated individually as sections of this report, but with the understanding that they are closely intertwined and inform each other. **Section 1** introduces Lake Auburn, outlines the motivation and purpose of the study, and gives key background information such as historical context and a summary of current conditions.

Section 2, Analysis of Regulatory Impacts, examines the regulatory framework protecting water quality. City of Auburn regulations are evaluated through literature review and comparative analysis using other water supply lakes and State and federal models. We found that the regulatory framework for the protection of Lake Auburn as a water supply is mostly robust and effective. We recommend several revisions that will better align the regulations with the best available science and State and regional norms and apply them more fairly across different land uses and activities:

- Align the septic system regulations contained in the Lake Auburn Watershed Overlay District Ordinance with the best available science and Maine's septic system regulations.
- Develop a clear set of standards for farm management that will limit phosphorus loading from commercial agricultural activities.
- Incorporate low impact development requirements for new single family residential development.

Section 3, Analysis of Environmental Impacts, analyzes the environmental impact of various development and water quality scenarios for the Lake Auburn watershed. The analysis uses a well-documented watershed model paired with in-lake empirical formulas to predict water quality outcomes under each future scenario. This section also reviews recreational uses of the lake, forest management, and the history of land purchases for water supply protection in the watershed. We find that Lake Auburn reached a tipping point in the 2010s where key environmental thresholds were reached or passed. In the lake, levels of phosphorus – a key nutrient for the growth of aquatic algae – rose above 10 parts per billion (averaged annually) and elevated the risk of algae blooms. Meanwhile, in the watershed, forested land cover dipped below 75% of the land area, meaning that more sources of phosphorus contamination, such as impervious surfaces, areas of bare soil, and septic systems, were contributing to the lake. Treatment of the lake with alum in 2019 was successful and achieved a temporary reset in lake phosphorus levels.

Looking forward, our model projects existing conditions and development rates ahead to 2100 (the "Business as Usual" scenario), by which time Lake Auburn will again near the tipping point of 10 parts per billion phosphorus, even with the regular use of alum treatments. Future scenarios that ease restrictions on residential growth will result in higher concentrations of phosphorus and higher risk of algae blooms. Requiring low impact development – innovative techniques that reduce impervious cover and encourage stormwater to pass through the groundwater before reaching the lake, thus filtering out contaminants – makes a small but significant positive impact on phosphorus and the risk of algae growth.

Section 4, Analysis of Economic Impacts, examines the costs and benefits of the same development and water quality scenarios for the Lake Auburn watershed that are covered by the environmental analysis in Section 3. The analysis combines well-established economic methods with data on land use and water quality to systematically evaluate how these scenarios change or reallocate costs and benefits. We find that the source of the largest increases in benefits in all future scenarios is the increase in property taxes collected by Auburn, which climb from $3.6 million to $9 million annually in the highest development scenario. Meanwhile, the source of the largest extra costs is in dealing with declining water quality in Lake Auburn, especially treating water in a filtration plant which is estimated at over $3 million annually. Table 4-7 provides a detailed summary of our estimated aggregate costs and benefits across all scenarios. We find that the added benefits to Auburn are mostly or entirely offset by increased costs to Lewiston, resulting in negligible net economic benefit to the communities served by Lake Auburn.

Section 5 provides a summary of key findings, a discussion on several topics that overlap the regulatory, environmental, and economic analyses, and a set of holistic recommendations for the City of Auburn and other stakeholders to consider:

1. The City of Auburn should not seek to ease the current resource protection zoning or consider rezoning portions of the watershed for increased density. Increased density and new opportunities for residential development are better suited to other areas of Auburn outside of the Lake Auburn watershed.

2. The Auburn Planning Board and City Council should take up our recommended ordinance revisions and, if acceptable in their current form, adopt them. These recommended revisions are fully elaborated in Section 2 and in a separate document to the City.

3. The City of Auburn should share the findings on aggregate economic impacts with all partners and stakeholders for use in an open, transparent, and thoughtful public discussion of the fairness, equity, and sustainability of the current cost sharing and benefit allocations, as well as practical ways forward.

4. The City of Auburn, the Auburn Water District, the City of Lewiston, and the Lake Auburn Watershed Protection Commission should fully support collaborative work with local governments, land trusts, private landowners, and other potential partners in the upper Lake Auburn watershed to control development and limit phosphorus loading.

5. The key Lake Auburn stakeholders should cooperatively conduct a comprehensive review and gap analysis of current water quality monitoring efforts carried out by both the Auburn Water District and Bates College in the Lake Auburn watershed. This initiative should produce a monitoring plan, create a position for a full-time, dedicated data manager, continue collaboration with Bates College on student-assisted monitoring, and consider creating a technical science advisory board to the Lake Auburn Watershed Protection Commission to establish or maintain key local, State, and regional partnerships for review and guidance on water quality issues.

6. Given its high probability of causing a filtration waiver violation, a swimming area will likely not be feasible for Lake Auburn at any time unless State and federal authorities sign off. If a swimming area were to be re-instituted at Lake Auburn, we provide many actions that would need to take place to ensure that the area does not contribute to water quality degradation. Refer to Swimming in Section 3.

7. Allowance of only small watercraft restricted to areas away from the water supply intake should continue, and improved stabilization techniques at vehicle and pedestrian access points along the lake shoreline should be implemented, along with clear and effective barriers to foot and vehicle access.

8. The Lake Auburn Watershed Protection Commission should coordinate with local youth conservation groups or AmeriCorps to perform annual maintenance of trails and install best practices that limit erosion of trails, especially those sections nearest the lake. In addition, surveying how much horse manure may be found on the trails to inform a reconsideration of horseback riding near the lake is recommended, as manure can be a significant nutrient source in sufficient quantities. Finally, it is recommended that the City acquire permanent recreational trail easements to LAWPC properties with trails for guaranteed public access in the future.

9. The Lake Auburn Watershed Protection Commission should develop a comprehensive natural resource management plan for their lands that focuses firstly on drinking water protection and secondly on wildlife habitat protection, with multiple management options offered. The plan should incorporate new mapping of critical resources such as streams, wetlands, vernal pools, cover types, and rare, threatened, and endangered species present.

10. The Lake Auburn Watershed Protection Commission should work with local conservation groups and land trusts to purchase land in the watershed outside of Auburn. We also recommend that the Commission consider putting all their properties into permanent conservation.

1 Introduction & Background

This section describes the motivation, purpose, objectives, and structure of this study. Here, we also summarize background information to set the stage for subsequent sections that detail the analyses of regulatory, environmental, and economic impacts. While the three sections on regulatory, environmental, and economic analyses are separated, much of their content overlaps or is interconnected. The final section of this report aims to pull together the three analyses into a series of synthesized conclusions and recommendations that the cities and water districts can use to make informed management decisions for the future.

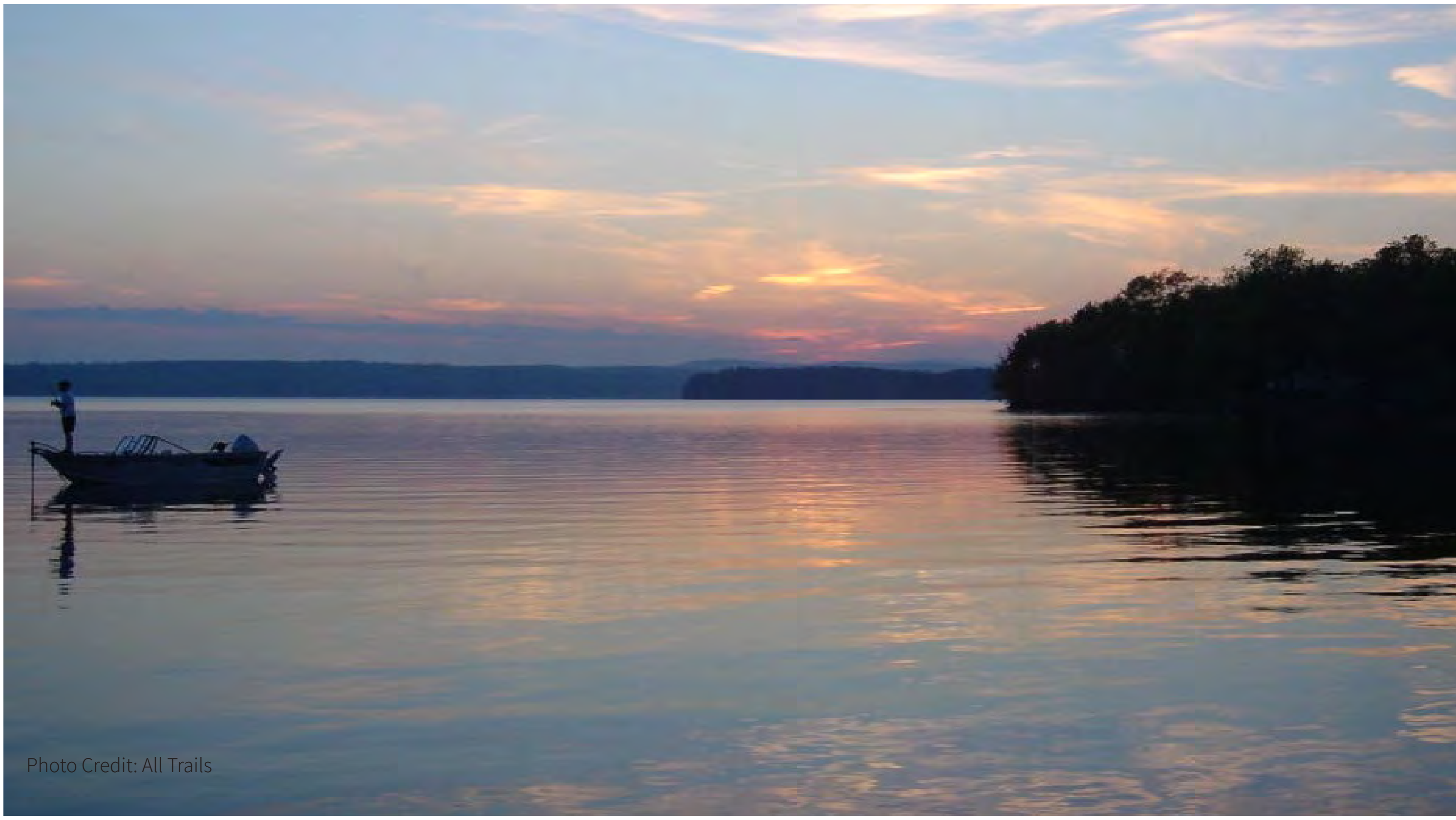

Photo Credit: All Trails

Purpose & Report Structure

Located entirely within the City of Auburn, Maine, Lake Auburn is the sole public water supply for over 39,000 consumers residing in Auburn, Lewiston, and a portion of Poland (Figure 1-1). Its history as a public water supply dates back to the 1870s, since which time many dedicated public servants, water quality professionals, and everyday citizens have reckoned with the complexities of planning for and protecting Lake Auburn as a high quality drinking water source. Faced with declining water quality in Lake Auburn in the last decade, the authorities in charge of supplying potable public drinking water from Lake Auburn have invested in several studies aimed at re-evaluating management approaches and decisions with respect to public water supply protection. The current report aims to provide a comprehensive analysis of the regulatory, environmental, and economic benefits and costs for scenarios that will maximize long-term public water supply protection of Lake Auburn, which the cities and water districts can use to make informed management decisions for the future.

For this report, the City of Auburn contracted the interdisciplinary consultant team of FB Environmental Associates, Horsley Witten Group, and the University of Maine to 1) carry out a thorough review of existing conditions, standards, regulations, and practices in Lake Auburn and its watershed, 2) quantify to the greatest extent possible the regulatory, environmental, and economic impacts of the current status quo and future scenarios, and 3) evaluate and recommend potential ways forward that maximizes the benefits and minimizes the costs of regulatory, environmental, and economic impacts to Lake Auburn, its watershed, and the surrounding communities. The final recommendations include both specific ordinance language improvements for City adoption, as well as holistic management changes, for improved public water supply protection. The consultant team applied a mix of methods and approaches to this complex set of issues, including tools from environmental planning, lake management science, environmental economics, and other disciplines and interdisciplinary fields. The common theme of all elements of our team's work is the commitment to unbiased, fact- and science-based data-gathering, analysis, and reporting.

To accomplish this set of objectives, the project team conducted three parallel, but intertwined, analyses that provide the structure for this report.

Section 2, Analysis of Regulatory Impacts, employs literature review, comparative analysis, and model standards in a critical evaluation of the existing regulatory framework for Lake Auburn. Recommendations for revisions to the City of Auburn's Zoning Ordinance are included in this section. As a separate deliverable associated with this report, we provided the City of Auburn with suggested revisions to existing ordinances directly within those applicable documents. The Planning Board and City Council may adopt those ordinance amendments at their own discretion.

Section 3, Analysis of Environmental Impacts, uses watershed water quality modeling techniques paired with in-lake empirical formulas to better understand existing water quality and predict water quality outcomes under a range of possible future scenarios. This section also reviews recreational threats and opportunities, current forestry practices, and LAWPC's land conservation strategy.

Section 4, Analysis of Economic Impacts, estimates the economic benefits and costs for a suite of development and water quality scenarios for the Lake Auburn watershed that were analyzed in Section 3. The analysis utilizes well-established economic methods, land use, and water quality information to systematically evaluate these scenarios.

Lastly, **Section 5, Synthesis, Conclusions, and Holistic Recommendations**, brings together the interconnected conclusions of the regulatory, environmental, and economic analyses and identifies key messages and broader implications for public water supply protection planning. The section concludes with holistic recommendations aimed at informing the public planning process at the highest level.

Background

At present, water supply for drinking water and fire protection are administered by the Auburn Water District (AWD), an independent utility with a board of trustees appointed by the Auburn City Council, and the Lewiston Water Division (LWD), part of the City of Lewiston Department of Public Works. Due to its long history of excellent water quality, Lake Auburn's water supply has been granted a 'Filtration Avoidance' waiver (hereafter, filtration waiver) by the US Environmental Protection Agency (EPA) for nearly 30 years, bypassing certain treatment requirements under federal drinking water law and saving the need for costly filtration infrastructure.

The lake and its watershed also provide a wide array of recreational opportunities. Recreational fishing is allowed on roughly two thirds of the lake. On land, hunting and trails-based recreation are allowed on many lands controlled by the Lake Auburn Watershed Protection Commission (LAWPC, or the Commission). Created in 1993 as a requirement of the filtration waiver issued to the AWD and LWD by the US EPA, LAWPC is an interlocal regulatory body with commissioners from all municipalities within the Lake Auburn watershed. LAWPC serves to protect the

Lake Auburn watershed for the purpose of continuing to provide a high quality public water source. LAWPC owns and manages many shoreline and watershed properties for water supply protection, in addition to carrying out many other watershed protection activities such as stormwater pollution prevention, water quality monitoring, and educational outreach to schools and the public at large. Dr. Holly Ewing of Bates College and her collaborators collect additional data on Lake Auburn's water quality and lake ecology in cooperation with AWD.

Along with Auburn, four other municipalities – the upper watershed towns of Turner, Minot, Hebron, and Buckfield – comprise the entire watershed area of 11,758 acres, including Lake Auburn at 2,298 acres (Figure 1-1). The Auburn portion of the watershed is the largest at 7,910 acres and is regulated by City of Auburn ordinances including base zoning and resource protection zoning. Recognizing that water supply lands deserve special protection and responding to a request from the AWD, in 1973 the City of Auburn implemented the Lake Auburn Watershed Overlay District to apply controls to agricultural use, waste disposal, erosion control, and construction within the watershed. Later in 1991, Auburn added the Phosphorus Control Ordinance, which further defined controls on stormwater that can carry phosphorus to surface waters. Shoreland zoning also applies to the lakeshore and to key tributaries such as Townsend Brook and the Basin. In recent years, there has been public debate about whether these restrictions are overly strict beyond what is needed to protect water quality, especially in light of a housing shortage in Auburn and the surrounding region. The counterargument by local groups is that the added risk to Lake Auburn's water quality would greatly outweigh any gains from loosening development restrictions.

Public sentiment is divided on whether the City of Auburn, the City of Lewiston, and the AWD should invest in more stormwater management technologies and improvements, more restrictive ordinances and better practices, proactive construction of a filtration plant, or some mixture of these approaches, and when water quality problems have arisen, public calls to action have often run in conflict with one another. Water quality in Lake Auburn continues to be generally excellent, but in 2011-12 and again in 2018 problems with algae blooms surfaced that threatened the filtration waiver. In 2012, a late summer-early fall algae bloom triggered low oxygen and a widespread lake trout mortality event (a.k.a., fish kill). In 2018, another late summer-early fall algae bloom caused persistent taste and odor issues and complaints by many in the communities served by Lake Auburn. Both the 2012 and 2018 events had their root cause in excessive phosphorus, a naturally occurring mineral that can allow algae to grow excessively, in turn triggering other shifts in the lake ecosystem and resulting in degraded drinking water quality and challenges in providing potable public water with the current treatment system. In 2019, the AWD and LWD partnered to implement an in-lake treatment using aluminum sulfate and sodium aluminate (a.k.a., alum) to lower phosphorus levels in the lake by stripping the water column and locking the mineral into the lake-bottom sediments. The alum treatment had its intended effect of lowering phosphorus levels, and water quality in 2019-20 was significantly better than in previous years. The key question moving forward is how Lake Auburn will respond to future patterns of development in the watershed, as well as to future changes in precipitation and temperature driven by climate change.

The economics of water supply protection are complex and intertwined with the regulatory and environmental aspects of managing Lake Auburn and its watershed. Direct costs associated with the AWD and LWD's water supply provisions are mostly passed on to Auburn and Lewiston ratepayers in the form of water and fire protection bills. Some of these direct costs are split evenly by the two municipalities, while others are split based on usage, which roughly breaks down to 60% to Lewiston and 40% to Auburn. In recent years, there have been public calls to revise the cost sharing arrangements in the name of fairness and equity, based on several points. First, Lewiston is larger than Auburn and uses more water, but costs are not universally broken down by actual usage. Second, all the water supply protection lands are located in Auburn, taking properties off Auburn tax rolls (Figure 1-1). These questions of equitable cost sharing were briefly considered in the economic analysis but were difficult to define in pure monetary terms.

The current situation with Lake Auburn water supply protection presents multi-dimensional challenges and questions. This study attempts to not only compile and synthesize the best available data but also to project the current state of affairs into the future alongside some select alternative future scenarios. While comprehensiveness is an overarching goal of this study, the project team acknowledges that no analysis can truly capture all the complexities of a dynamic social-ecologic-economic system such as Lake Auburn's water supply, much less consider the entire range of possible future scenarios and outcomes.

Further details to supplement the history of Lake Auburn water supply protection efforts can be found in several previous studies (CDM Smith, 2013, 2014; CEI Inc., 2010), as well as in the following sections.

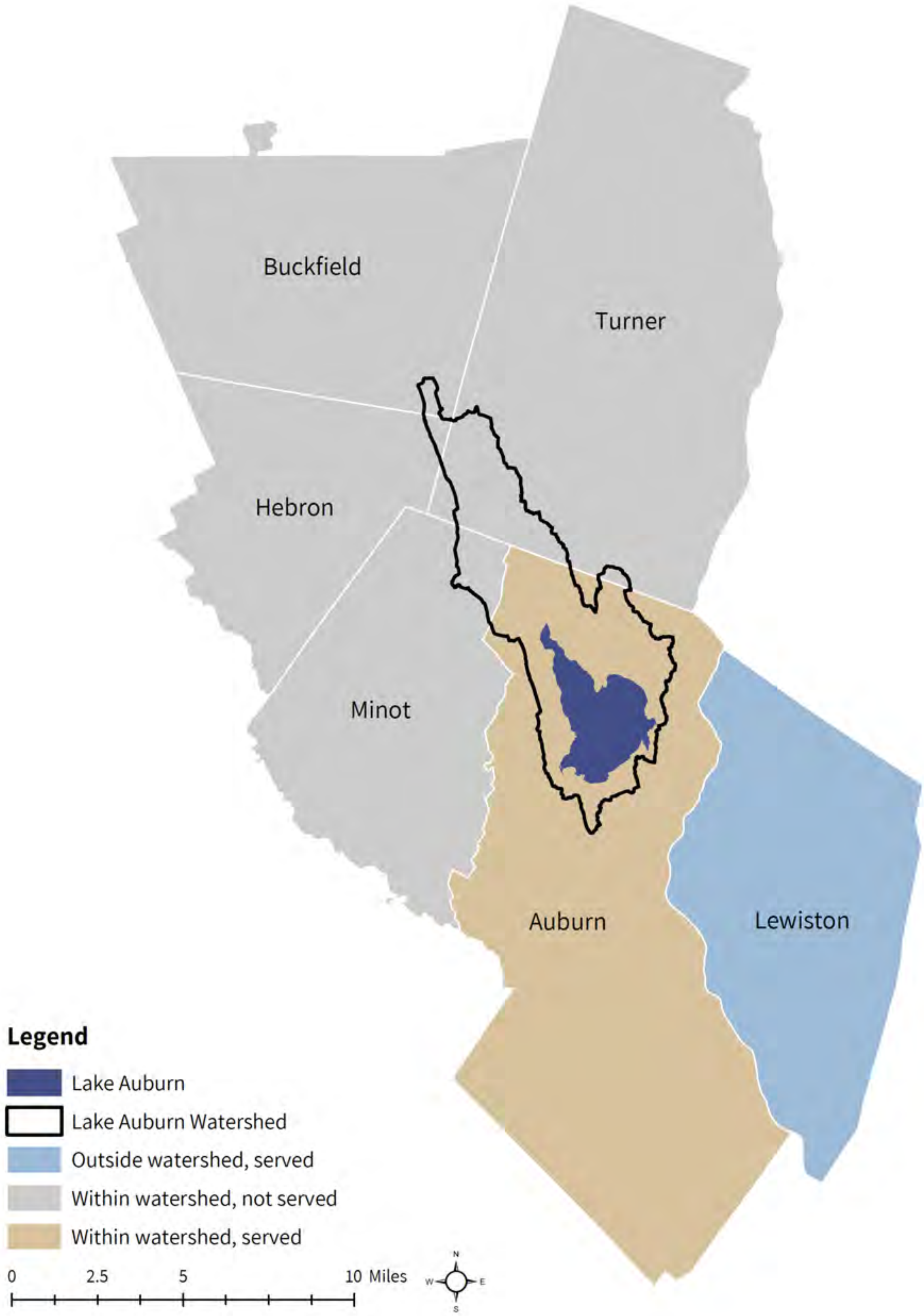

Figure 1-1. Towns within the watershed of or served by the Lake Auburn public water supply. Lake Auburn is located entirely within the City of Auburn and serves the communities of Auburn and Lewiston, but the Lake Auburn watershed extends into the headwater communities of Turner, Minot, Herbon, and Buckfield, who receive no benefit from the water supply but impact its quality.

2 Analysis of Regulatory Impacts

This section reviews and analyzes the existing regulatory framework for the protection of Lake Auburn, including City of Auburn ordinances, applicable Maine state laws and regulations, and relevant Auburn Water District/Lake Auburn Watershed Protection Commission by-laws. The analysis employs literature review, comparative analysis, and standards from state and federal models for effective water supply protection to develop recommendations to update, simplify, and strengthen provisions of the regulatory framework while avoiding unnecessary or inequitable regulatory impacts to stakeholders. This section concludes with a historical land use and buildout analysis based on current regulations, the results of which were used to inform the future scenarios in later sections.

Photo Credit: Sun Journal

Ordinance Review

Requirements of the Filtration Avoidance Waiver

Lake Auburn serves as a public drinking water supply for customers in Auburn and Lewiston. Because of its history of high quality water and effective watershed management, it received a filtration avoidance approval from EPA and the State of Maine in 1991. In accordance with 40 CFR Section 141.71, Criteria for Avoiding Filtration under the National Primary Drinking Water Regulations, a public water supply that uses a surface water source without filtration must maintain certain source water quality and watershed conditions, including the following:

- The fecal coliform concentration must be equal to or less than 20 cfu/100 mL or the total coliform concentration must be equal to or less than 100 cfu/100 mL in representative samples of the source water immediately prior to the point of disinfectant application in at least 90% of the measurements made for the 6 previous months on an ongoing basis.
- Turbidity level cannot exceed 5 NTU in representative samples of the source water immediately prior to the point of disinfectant application unless: (i) the State determines that any such event was caused by circumstances that were unusual and unpredictable; and (ii) as a result of any such event, there have not been more than two events in the past 12 months during which the system served water to the public or more than five events in the past 120 months during which the system served water to the public. An "event" is a series of consecutive days during which at least one turbidity measurement each day exceeds 5 NTU.
- In addition, the public water system must maintain a watershed control program which minimizes the potential for contamination by *Giardia lamblia* cysts and viruses in the source water.

In 1993, the LAWPC was established by mutual agreement between the AWD and LWD to preserve water quality in Lake Auburn, with maintenance of the filtration waiver a primary objective. The LAWPC was given authority to protect the watershed in several ways, including acquiring, owning, and managing lands in the watershed as water supply protection lands. In addition, the LAWPC was to provide intermunicipal oversight of the watershed management plan. In authorizing LAWPC, as stated in the LAWPC by-laws,

> *"The Legislature of the State of Maine has specifically authorized and delegated to the Trustees of the Auburn Water District the authority to promulgate by-laws regulating and restricting recreational and other uses of Lake Auburn as may be required to preserve the purity of the water in said Lake and to protect it as a public drinking water supply."*

The LAWPC established through its by-laws four zones of protection in the watershed with associated restrictions in each zone. These zones are:

- Level 1 In-take Restricted Zone
- Level 2 Shoreline Protected Zone
- Level 3 Lower Watershed
- Level 4 Upper Watershed

Key among the restrictions is a prohibition of access to the lands of Zone 1 and a prohibition of water related activities in Zone 1. The term "water-related" activities include, without limitation, any activity in, on, or from the surface waters of the lake or the watershed, such as swimming, boating, water skiing, sailboarding, canoeing, kayaking, jet skiing, sailing, fishing, or diving, and the landing or taking off of seaplanes. In Zone 2, a prohibition of all water-related activities, as described above, except for the allowance of small recreational boats used without human contact with the water. Boats with onboard toilets and sleeping facilities are prohibited. In addition, gatherings of 50 or more people within 100 feet of the lake or on the lake require a permit from the AWD. While these restrictions were formalized in 1992 with the adoption of the LAWPC by-laws, a ban on bathing in Lake Auburn was initiated as early as the late 1800s (CEI, Inc., 2010).

Existing Regulatory Framework in the Watershed

The Lake Auburn watershed is regulated by the Auburn Zoning Code, which includes several applicable zoning districts in the 'base code' as well as the Lake Auburn Watershed Overlay District Ordinance (Article XII, Division 4 of the City Ordinances), the Shoreland Overlay District Ordinance, which includes the additional establishment of the Shoreland Resource Protection Overlay (Article XII, Division 5 of the City Ordinances), and the Phosphorus Control Ordinance (Article XII, Division 2 of the City Ordinances). The Lake Auburn Watershed Overlay District Ordinance and the Phosphorus Control Ordinance apply to all land within the watershed, while the Shoreland Overlay District Ordinance applies to lands within 250 feet of the Normal High Water Mark of Lake Auburn and contributing streams and ponds within the City of Auburn. The Shoreland Resource Protection Overlay applies within the Shoreland Overlay District to properties owned or controlled through development restriction easements by the LAWPC that are deemed to be appropriate for resource protection zoning by a vote of the commission, all in addition to the underlying ordinances. Appendix 1 highlights the key provisions, authority, and permitting requirements of the Phosphorus Control Ordinance and the Lake Auburn Watershed Overlay District Ordinance.

Within the Lake Auburn watershed, most land is zoned as Agriculture and Resource Protection, followed by Rural Residential and then Low Density Country Residential. This distribution creates a pattern in which the larger roadways through the watershed are flanked by zoning that permits residential development on 1-acre or 3-acre minimum lots, and the land behind those lots is zoned for Agriculture and Resource Protection in which minimum lot sizes are much larger, at 10 acres, and uses are restricted generally to agriculture, timber management, and associated single family residential development.

Onsite Septic System Regulation

From interviews with key stakeholders and discussions with City and AWD staff, we heard that a key constraint to development is the onsite septic system requirements in the Lake Auburn Watershed Overlay District Ordinance, which have been interpreted as a de facto prohibition of the installation of septic systems on sites with certain geologic and soil conditions. When combined with other zoning lot sizes and allowable use restrictions, the regulations have the effect of limiting new residential development in much of the watershed. The language in the requirements is as follow:

> *"Subsurface absorption areas shall not be permitted on sites on which the highest seasonal groundwater table, bedrock, or other impervious layer is less than 36 inches below the bottom of the organic horizon. Not less than 24 inches of suitable soil shall be present below the bottom of the subsurface absorption area. The bottom of such subsurface absorption area shall not be less than 12 inches below the bottom of the organic horizon measured from the lowest point on the subsurface absorption area."*

It appears that the language is unnecessarily restrictive from the perspective of water quality protections. Understandably and logically, there is value in establishing septic system requirements in the Lake Auburn Watershed Overlay District, such as an increased depth to groundwater below the leachfield, that are more protective than the Maine state standards. By establishing an outright prohibition of subsurface disposal systems on certain sites, the ordinance does not take into account the ability of subsurface disposal systems to incorporate adaptive design elements that are equally or more effective in removing pollutants from the discharge. The State septic system requirements allow for the use of alternative designs, such as mounded disposal systems and drip irrigation systems, that can be effectively installed in areas with shallower depth to groundwater.

Traditional onsite septic systems are designed for pathogen removal and are not designed specifically for the removal of other wastewater pollutants, including phosphorus, nitrogen, viruses, and other contaminants of emerging concern (e.g., PFAS, pharmaceuticals). Traditional onsite septic systems will mineralize organic nitrogen to ammonia and nitrify ammonia to nitrate with some possible reduction of total nitrogen through the leachfield, underlying soils, groundwater, and surface waters where it can move from water to the atmosphere through denitrification. Unlike nitrogen, there is no analogous pathway of phosphorus removal to the atmosphere or some other harmless form. In the best case scenario, phosphorus "removed" from waste will remain bound in soil particles or recycled in plant growth. Nutrient removal can be enhanced with alternative septic systems, which are continually under development and testing; viruses and contaminants of emerging concern are a universal challenge and an area of cutting-edge research. Generally, the proactive approach is to first limit the density of development.

The Massachusetts Alternative Septic System Testing Center (Testing Center) in Barnstable County, Cape Cod, MA is currently exploring the effectiveness of different onsite treatment and disposal systems in removing phosphorus from leachate, as this is a growing concern primarily for lakes and ponds. An early analysis and literature review (circa 2005) by Heufelder and Mroczka at the Testing Center still serves as a leading reference on this as-yet somewhat understudied issue. As a preface to a discussion of design alterations to traditional septic systems that can improve phosphorus removal, the report states:

> *"Although the principles involved in the removal of phosphorus within soil absorption systems are not completely understood, there are general principles that, if applied, offer the opportunity to enhance phosphorus treatment in the standard septic system. These principles are as follows:*
>
> - *Finer textured soil offers greater ability to adsorb phosphorus compared with coarse sands.*
> - *The removal of phosphorus in any soil absorption system is related to the volume of soil that the percolating effluent is exposed to.*
> - *The more aerobic and non-reducing unsaturated-zone environments have a higher capability to remove phosphorus.*
> - *Soils containing a higher content of metal oxides (i.e., iron and aluminum in acidic soils and calcium in basic soils) have a greater ability to sequester phosphorus.*
> - *Shallower placements of the soil absorption system offer the ability of plant-root penetration and hence offer another mechanism and opportunity for phosphorus removal.*

Table 2-1. Comparison of Septic System Design Regulations in New England States.

State	Septic System Regulation	Date of Updated Regulation	Minimum Separation Distance	Post Construction Inspection Required?	Inspections Recommended?
CT	Regs. Conn. State Agencies §19-13-B100a.	2015 (Technical Design Standards)	1.5 ft (non-coastal areas) to 2 ft (if soil percolation is faster than 1 min per inch)	No	Local directors of public health perform inspection "when deemed necessary."
MA	310 CMR 15.000 ("Title V")	2016	4 ft (if soil percolation is slower than 2 min per inch) to 5 ft (if soil percolation is faster than 2 min per inch)	Yes. Septic systems must be inspected when property is sold, increased flow, or expanded. If alt/innovative system, then required quarterly inspections.	N/A
ME	10-144 CMR Ch. 241	2015	12-48 inches. Not allowed in A1 or E soil conditions inside shore land area.	No	State recommends new buyers get septic inspected.
NH	Env-Wq 1000	2016	2ft - 4ft, depending on slope of site and components of system	No	State recommends local health officers conduct inspection once every three years.
RI	R.I. Code R. 25-16-17:32, 39	2016	2 ft in all watersheds, except 4 ft in "critical resource area" watersheds. Mandatory advanced N-removal technologies in CRA watersheds. Requires new system (conventional or alternative/innovative) if the current system is a cesspool near a public drinking water supply, a public well, or a bordering tidal water area.	No	State may at its discretion inspect any aspect of the installation, but not statutorily required (system designer is responsible for this). Existing systems inspected under town wastewater management programs.
VT	Vt. Admin. Code §16-3-300	2007	Prescriptive = 2 ft; Enhanced Prescriptive = 1.5 ft; Performance Based = 6 inches plus calculated induced groundwater mounding	No	After installation, inspections are done at the discretion of the State.

Source: Adapted from Mihaly, 2017. With updates for Maine.

- *Phosphorus is more mobile under saturated conditions, especially if those conditions are reducing conditions."* Note that this is a similar mechanism to internal phosphorus release from lake-bottom sediments under anoxic (low-oxygen, reducing) conditions.

A potential revision to the Lake Auburn Watershed Overlay District Ordinance is presented in a separate document to the City of Auburn. This revision incorporates the State Plumbing Code (the Maine Subsurface Wastewater Disposal Rules [CMR 10-144 Chapter 241, last amended August 3, 2015]) requirements with an increase in depth to groundwater, bedrock, or other restrictive layers of 36 inches, rather than the shallower depths allowed by the less protective tiers in the State code. The State code was last updated in 2015 to require a depth of between 12-24 inches of native soil below the leach field. Prior to this update, the requirement was as little as 9 inches in many cases. The Maine requirements are less stringent than other New England states (Table 2-1). The potential revision presented above is a simple approach to revising the language to maintain both the greater depth to groundwater requirement that reflects the existing local code and the common and familiar set of standards (the Plumbing Code) but also allows for alternative onsite septic disposal approaches that can improve phosphorus control from septic systems. Using a clear reference to the State Plumbing Code with a single revision provides a simple approach to updating the local ordinance, assuming that designers and regulators will be familiar with the State code. In addition, it allows projects in the watershed to take advantage of the provisions in the State code that allow the use of innovative and alternative designs in place of a traditional septic system leach field, including drip irrigation and proprietary devices, that may be useful and effective in the watershed.

Farm and Forest Management

The Phosphorus Control Ordinance (Article XIII, Division 2 of the Code of Ordinances) is aimed specifically at limiting phosphorus loading to Lake Auburn and Taylor Pond from land development. This ordinance incorporates Maine's phosphorus export coefficient (F), which is the amount of phosphorus export from the watershed to the lake that will increase the lake's annual average phosphorus concentration by one part per billion (ppb). The coefficient F for the Auburn portion of the Lake Auburn watershed is 109.9 lbs/ppb/yr or 49.8 kg/ppb/yr (Maine Stormwater Management Design Manual, Volume II, Appendix C, last updated November 1, 2017). The ordinance establishes erosion controls to limit sedimentation to both lakes, but because of other zoning restrictions in the Lake Auburn watershed, as well as the exemptions provided in the ordinance itself, it mostly affects single family residential projects in the Agriculture and Resource Protection, Rural Residential, and Low Density Country Residential districts that impact more than 10,000 square feet or include a building or structure with 575 square feet of ground floor area, as well as roadway construction/reconstruction projects that impact more than 1,500 square feet. The ordinance does not clearly define the limit of a project area that must be managed to meet the required phosphorus controls. A clarification of this point could strengthen the ordinance, for example, by stating that the 'permit' area or 'project' area is defined by the area of alteration or disturbance associated with the given project.

Exemptions are provided for timber management or harvesting operations conducted according to a management plan prepared and supervised by a registered forester or the AWD, as well as for agricultural uses following a soil and water conservation plan approved by the Androscoggin County Soil and Water Conservation District. These exemptions turn over regulatory and enforcement controls to other agencies that are not necessarily required to follow the same phosphorus controls, unless a particular landowner chooses not to develop one of the exempted management plans.

In order to retain the effectiveness of the Maine DEP Manual across the Auburn portion of the watershed and to allow the City oversight to ensure that erosion control plans are developed and implemented in accordance with the Maine DEP Stormwater Design Manual (ME DEP, 2016) "Phosphorus Control and Lake Watersheds – A Technical Guide to Evaluating New Development" (also known as the Phosphorus Control Manual), the City should consider removing the above-referenced exemptions in the Phosphorus Control Ordinance. Instead, the City could require timber management and harvesting operations to be conducted in accordance with a management plan prepared and supervised by a registered forester, and agricultural uses to be conducted in accordance with a soil and water conservation plan approved by the Androscoggin County Soil and Water Conservation District (ACSWCD), in addition to meeting the erosion and sediment controls and best management practices outlined in the ordinance. Refer to Forest Management in Section 3 for additional recommendations. This additional regulatory oversight of land use, particularly agriculture, is an important element in addressing the activities on the landscape that appear to have an outsized effect on the quality of Lake Auburn, based on the environmental impact analysis conducted for this project.

According to the Lake Auburn Watershed Overlay District,

> *"All uses of land for chicken farms, cattle farms, horse farms, egg farms, piggeries, sheep farms, stables, crop farming and other agricultural purposes shall be subject to the approval of the city water district. Such approval shall be granted upon a showing that such uses will not cause groundwater contamination or contaminate or disturb the normal course of surface water runoff."*

However, the ordinance does not provide any additional guidance for how the AWD should or would evaluate the threat of contamination from such land uses. Furthermore, as stated above, exemptions from the Phosphorus Control Ordinance are provided for agricultural uses conducted according to a soil and water conservation plan approved by the ACSWCD. This oversight structure results in a dual responsibility for farm plan review and approval between the AWD and the ACSWCD, which do not necessarily serve the same public interests or apply the same performance standards for plan approval. In addition, this approach removes any ability for the City itself, separate from the AWD and the ACSWCD, to enforce the management plans.

One approach to reducing and limiting phosphorus loading in the future is to place a concrete limit on the amount of farming operations in the watershed, which appears unlikely and counter to much of the ACSWCD efforts in the region. Another approach is to develop a clear set of standards for farm management that will be consistently applied to farms in the watershed for the purpose of controlling erosion and limiting the delivery of excess phosphorus from the farm practices to Lake Auburn. This approach would also benefit from establishing a clear enforcement mechanism to ensure that the City, perhaps in addition to or in concert with the AWD, has the ability to enforce the management plans as they relate to water quality protection.

An additional method to reduce erosion and delivery of soils and phosphorus from agricultural lands to surface waters in the Lake Auburn watershed is to improve the buffer requirements on the downgradient boundaries of all agricultural lands, both tilled lands and livestock areas if allowed. The Lake Auburn Watershed Overlay District Ordinance currently states,

> *"Agricultural Buffer Strip – Where land adjoining Lake Auburn or its perennial tributaries is tilled for agricultural purposes, an untilled buffer strip fifty (50) feet wide shall be retained between the tilled area and the normal high water mark. This Subsection shall not be interpreted as permitting agricultural tillage in any zoning district in which it is not otherwise permitted."*

As such, this buffer is only required along shoreline areas. However, a buffer can be additionally effective in reducing the movement of sediment toward the waterbody if it is placed at the downgradient edge of the tilled area, perpendicular to the natural flow of water, wherever that tilled area sits in the watershed, and if that buffer is greater in width. An increase to 75 feet or 100 feet can increase the ability of the buffer to intercept sediment on the move. Furthermore, the existing ordinance language does not explicitly define the required condition of the buffer other than that it is 'untilled.' In order to be effective, the buffer should be vegetated to slow, filter, and capture runoff and sedimentation that may originate from the adjacent lands in agricultural use. An existing vegetated buffer should be maintained, or in the case that vegetation is not present in the buffer area, the buffer should be revegetated with a combination of native, non-invasive vegetation. The City could eventually consider defining the requirements for the composition of a newly vegetated/restored buffer, including allowable plant species and structure, density of plantings, and other details. A buffer requirement is likely to be included in an appropriate farm management plan, but including this requirement clearly and explicitly in the ordinance provides more assurances that it will be implemented.

Residential Land Development and Low Impact Development

As noted above, the Phosphorus Control Ordinance, in effect, applies primarily to residential development. For residential development that does fall under the Phosphorus Control Ordinance, the ordinance relies on the State standards in the Phosphorus Control Manual. One way to strengthen the controls and reduce the potential for erosion during construction and clearing is to reduce the applicability threshold of 10,000 square feet of impact to a lower amount such as 5,000 square feet. However, based on the type of development expected in the watershed under existing zoning, it is not clear that reducing this threshold would actually capture additional projects. Therefore, an approach that first defines the 'permitted project area' and then addresses the design and layout of the expected development is likely to be more effective. In Section C.1 of the Phosphorus Control Ordinance, the applicability of the ordinance requirements is attributed to 'land uses' that are not in fact land uses but instead types of land disturbance projects. A simple language revision will clarify that the requirements do not apply to a given land use but to a demarcated limit of disturbance, such that all disturbance within that area is required to meet the erosion and sedimentation controls and other phosphorus controls. The proposed revision is presented in a separate document to the City.

In addition to the techniques, practices, and structural changes described above, the use of low impact development (LID, also known as low impact design) can also help to limit the impacts of stormwater runoff and associated erosion and pollutants from sites once they are completed. This approach uses the layout of the proposed project to limit the generation of stormwater runoff on a site and reduce pollutant loading carried in the stormwater that is generated. The LID Guidance Manual for Maine Communities (Horsley Witten Group, 2007) describes approaches for implementation of LID practices at the local level. The goal of this non-binding guidance document is to assist communities in promoting or requiring LID practices on small scale projects that fall below the typical State Stormwater Law (also known as Chapter 500 after the DEP administrative rules chapter) permit thresholds, such as single family homes in a rural or suburban district. The themes in this guidance are bolstered in the more recent Maine Stormwater Design Manual, particularly in Chapter 4 of Volume 1 and Chapter 6 of Volume 2 in which these standards are more fully codified. The guidance document walks the user through the selection of appropriate LID practices based on land use type and setting, and specific type of source area (e.g., rooftops, non-rooftop impervious areas, lawns). LID practices appropriate for single family residential lots include rain gardens, vegetated swales, vegetated buffers, dry wells, infiltration trenches, pervious pavements, and rain barrels or cisterns. The guidance document then walks the user through a set of basic design standards to reduce runoff generation and pollutant loading from new single family residential development. The standards as they apply to a water supply watershed are presented below:

- Disturbance on an individual lot must be less than 15,000 square feet (including building, driveway, walkways, lawn area, construction access, and grading).
- A minimum natural vegetated buffer must be maintained downgradient of all developed areas on the lot. This buffer shall be 50 feet wide if naturally forested or 75 feet wide if maintained as a natural meadow.
- No more than 7,500 square feet of impervious cover is located on the property.
- A minimum of 40% of the lot area must be maintained as undisturbed natural area. If the existing land has been disturbed by prior activities, a natural vegetated

buffer and/or undisturbed natural area may be proposed through restoration and revegetation.

Volume II of the Phosphorus Control Manual outlines a calculation process to determine a project's phosphorus allocation and mitigation achieved through different mitigation measures, including LID. The Auburn Phosphorus Control Ordinance includes language that mimics this manual but incorporates a factor of protection of 0.5, which is appropriately more protective than the factor assigned by DEP to Lake Auburn. In conjunction with the factors already included in the City's ordinance, the calculations in this manual can be integrated into the local approval process for single family parcels that would otherwise fall under the Chapter 500 statewide stormwater regulations. Chapter 500 of the Maine State Code presents stormwater management requirements for activities licensed under the State's Stormwater Management Law (generally applies to projects that disturb 1 acre or more) and Site Location of Development Law (generally applies to projects 20 acres or larger or projects that propose 3 or more acres of impervious cover). The implementation of these standards for single family residential development on lots of up to 3 acres, such as those currently allowed in the Rural Residential and Low Density Country Residential districts in the Lake Auburn watershed, can help to reduce the pollutant loading contribution typically generated by residential development. A potential simple revision to incorporate this approach to the Phosphorus Control Ordinance is provided in a separate document to the City. In addition, the revision includes an update to the name of the applicable DEP manual referenced in the ordinance, to correctly reference the March 2016 Stormwater Management Design Manual, Volume II, Phosphorus Control Manual, which is currently being considered by the City.

Conclusions and Recommendations

Based on a review of the existing ordinances that govern land uses in the Lake Auburn watershed and aim to protect the water quality in Lake Auburn, we have identified a number of recommendations to improve the ordinances through clarification of the standards, applicability, review process, and enforcement ability. The recommendations discussed above are summarized in conclusion as follows:

- Avoid higher-density residential development in the Lake Auburn watershed. The lower density zones that currently predominate in the watershed allow sufficient lot sizes for septic system design and stormwater control that are appropriate for water supply protection. Section 3 of this report characterizes the additional risk that new development carries for lake water quality and the water supply, and dense development exacerbates those risks by generating more phosphorus load from the same land area. Accordingly, we recommend that the City seek opportunities for higher-density development elsewhere, outside the lake watershed, that will not carry risks to the lake or the water supply. The eastern portion of East Auburn and the Androscoggin River are two such areas of Auburn that the City should consider, complete with the same amenities such as walkability and water views as would-be development on the lake.

- Revise the septic system requirements of the Lake Auburn Watershed Overlay District Ordinance to incorporate the Maine Subsurface Wastewater Disposal Rules, including provisions that allow for mounded leach fields and other state-approved alternative designs, while incorporating a more protective requirement for depth to groundwater or bedrock below the leachfield. Refer to Appendix 2 for a summary.

- Rather than effectively exempting timber and agricultural activities from City zoning oversight under the Phosphorus Control Ordinance, these activities should be required to meet the erosion control requirements in the ordinance in addition to seeking approval from outside entities (registered forester or ACSWCD and AWD) for approval of their operation and management plans.

- Adjust the agricultural buffer strip requirement in the Lake Auburn Watershed Overlay District Ordinance to improve its effectiveness. Recommended adjustments include widening the buffer to 75 or 100 feet, requiring the buffer to be vegetated and requiring a buffer to be located downgradient of all agricultural activities, perpendicular to the direction of overland flow, in all areas of the watershed instead of only being required adjacent to surface water.

- Incorporate low impact development requirements for single family residential development on the 1- and 3-acre lots allowed in the Lake Auburn watershed by way of referencing the Maine Stormwater Management Design Manual, Volume 2.

Service layer Credits: Source: Google Earth 5/4/2018

Figure 2-1. Aerial view of representative development patterns in each town in the Lake Auburn watershed. Green lines represent the watershed boundary; yellow lines represent town boundaries, and semi-transparent white shading represents areas outside the watershed.

Land Use History & Development Pressures

State and local regulations dictate land use change in any given locality. Land use changes within a watershed over time can have measurable consequences on receiving water quality. As watersheds become more developed with commercial, residential, and industrial land uses, the amount of forest that would naturally help infiltrate precipitation may be converted to impervious surfaces, such as rooftops, roads, parking lots, and sidewalks, which force untreated and often polluted runoff to surface waters. Understanding the type and rate of land use change within a watershed can help target effective restoration strategies, including public outreach and ordinance revisions.

We completed a land use change analysis for the Lake Auburn watershed. The 2013 (Updated 2018) City of Auburn Land Cover data file and the 2001 Maine Land Cover Database (melcd) were used as our baseline from which we manually created land use data files for other time periods, namely 1997, 2010, and 2020. Land use categories were matched between the two data sources and simplified to 16 categories, matching the MapShed model land use categories. We first overlaid recent data layers for roads, building footprints, wetlands, and streams from town, state, or federal databases. Next, we manually edited the data layer in ArcMap 10.6.1 using recent ESRI basemap aerial imagery (7/2019) and Google Earth Pro imagery (6/2018) to create a 2020 land use layer. Using Google Earth Pro imagery for 5/1997 (or 5/1998 when 5/1997 was blurry) and 5/2010, we compared each time period with 6/2018 to detect changes in land use. Any change was updated manually in ArcMap 10.6.1 for the appropriate land use data file year. We maintained a resolution scale of 1:500 when reviewing aerials and updating land use data files to ensure a similar level of accuracy and comparability among time periods.

The 11,758-acre Lake Auburn watershed (including Lake Auburn) covers the Maine towns of Auburn (7,910 acres, 67%), Turner (2,620 acres, 22%), Minot (885 acres, 8%), Hebron (184 acres, 2%), and Buckfield (159 acres, 1%). Though still largely forested, development patterns in the Lake Auburn watershed range from dense urban residential and commercial development to rural agricultural and low-density residential development (Figure 2-1). Large patchworks of agricultural land, including crop, hayfield, and pasture, with low-density residential development along secondary roads, are concentrated in the northern portion of the watershed. Only one major route crosses the watershed: Route 4 north-south in the southeastern (Auburn) portion of the watershed.

Table 2-2. Area (acres) by major land use type in 1997, 2010, and 2020 (and net total change for 1997-2020) and changes in area (acres) by major land use type from 1997-2010 and 2010-2020 (and percent net total change for 1997-2020) for five towns in the Lake Auburn watershed. Grey- and red-highlighted values represent an increase and decrease in land use type from 1997 to 2020, respectively.

Year	Land use	Data Type	Total Area by Major Land Use					Change in Total Area by Major Land Use				
			Auburn	Turner	Minot	Hebron	Buckfield	Auburn	Turner	Minot	Hebron	Buckfield
1997	Agriculture	Land use Area (Acres, %)	358.5	145.4	85.1	6	49.6	NA	NA	NA	NA	NA
	Forest		4,521.00	2,112.50	740.1	153	105.3	NA	NA	NA	NA	NA
	Urban		548.2	123.6	53.5	23.7	3.2	NA	NA	NA	NA	NA
	Water/Wetland		2,488.10	232.1	7.5	2.2		NA	NA	NA	NA	NA
2010	Agriculture		319.2	130.1	76.2	6	49.9	-39.4	-15.2	-9	0	0.3
	Forest		4,510.70	2,042.00	734.8	151.3	104.9	-10.2	-70.5	-5.2	-1.7	-0.3
	Urban		597.8	209.3	67.7	25.4	3.2	49.6	85.7	14.2	1.7	0
	Water/Wetland		2,488.10	232.1	7.5	2.2		0	0	0	0	0
2020	Agriculture		324.6	143	74.8	6	49.9	5.5	12.9	-1.3	0	0
	Forest		4,488.50	2,024.00	727.9	151.3	104.9	-22.2	-18	-6.9	0	0
	Urban		614.5	214.4	76	25.4	3.2	16.7	5.1	8.2	0	0
	Water/Wetland		2,488.10	232.1	7.5	2.2		0	0	0	0	0
1997-2020	**Agriculture**	**Change in Land use Area (Acres, %)**	**-33.9**	**-2.3**	**-10.3**	**0**	**0.3**	**-0.40%**	**-0.10%**	**-1.20%**	**0.00%**	**0.20%**
	Forest		**-32.4**	**-88.4**	**-12.1**	**-1.7**	**-0.3**	**-0.40%**	**-3.40%**	**-1.40%**	**-0.90%**	**-0.20%**
	Urban		**66.4**	**90.8**	**22.5**	**1.7**	**0**	**0.80%**	**3.50%**	**2.50%**	**0.90%**	**0.00%**
	Water/Wetland		**0**	**0**	**0**	**0**	**0**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**

Overall, between 1997 and 2020, the five towns in the Lake Auburn watershed experienced a net decrease in forest (135 acres) and agriculture (46 acres) and a net increase in urban development (184 acres) (Table 2-2; Figure 2-2; refer to Appendix 3 for maps showing land use change by town). More specifically, residential development largely replaced forested areas and cropland. However, there were instances where developed or agricultural lands were reforested. Much of this development occurred rapidly from 1997 to 2010 and has since declined. Despite covering only 22% of the watershed, Turner experienced the most land conversion to development.

We also ran a buildout analysis for the Lake Auburn watershed using ESRI ArcMap v. 10.5 and CommunityViz v. 4.3 to project future development pressures on land use change and ultimately water quality. The results of the analysis provided estimates of the numbers of potential lots and new building units the watershed may see developed at some point in the future, given existing environmental constraints to development and current zoning standards. To determine where development may occur in the watershed, the buildout analysis first subtracts land unavailable for development due to physical constraints, including environmental restrictions (e.g., steep slopes, existing buildings, wetlands, resource protection zones, hydric soils, and conserved land), zoning restrictions (e.g., shoreland zoning, street Right-of-Ways (ROWs), minimum lot sizes, and building setbacks), and practical design considerations (e.g., lot layout inefficiencies), then subdivides the remaining buildable land to the smallest units allowed under current zoning and places a point representing a building in each unit. Zoning standards used for the Lake Auburn watershed for each town are shown in Table 2-3. We considered LAWPC-owned lands to be protected from development indefinitely. We also used county-level soil data to restrict development from areas with less than 36 inches to groundwater or some restrictive layer where septic systems are not currently allowed to be constructed, as well as from areas within sandy soils within 300 feet of the Lake Auburn shoreline. Lakes and large ponds were given a 100-foot setback, and other waterbodies, streams, and wetlands were given a 75-foot setback. Development constraints used for input to the buildout analysis are shown in Figure 2-3.

Note that the data used in the analysis represented stock data sets obtained from New Hampshire's Statewide Geographic Information System Clearinghouse (NH GRANIT) online data catalog. Many of these data layers were created from remotely-sensed data (e.g., aerial photography, digital orthophotos, and satellite images) and large,

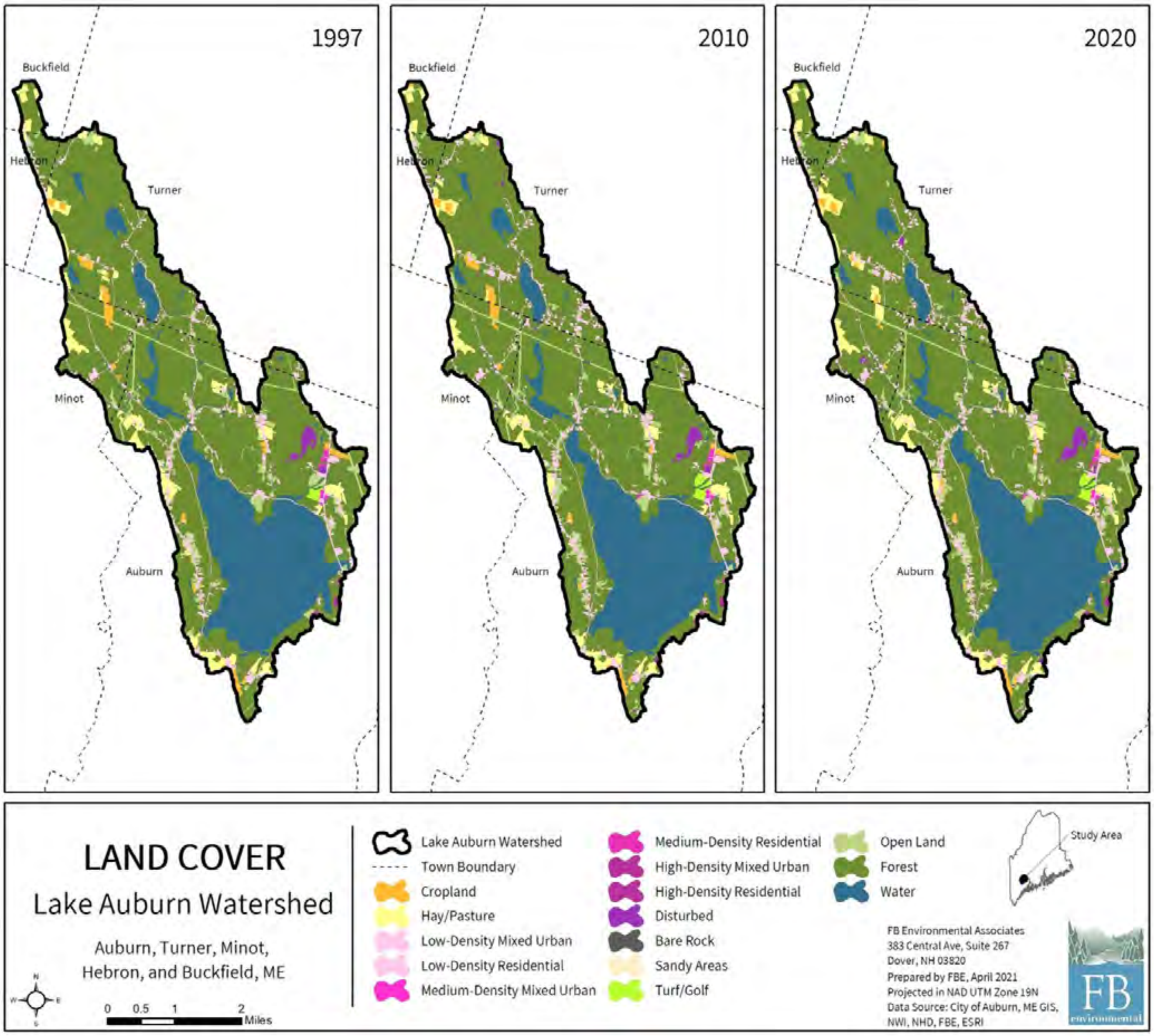

Figure 2-2. Land cover change from 1997 to 2010 to 2020 in the Lake Auburn watershed. Maps of land cover change by town are provided in Appendix 3.

landscape-level mapping projects (e.g., Soil Units). As a result, the data layers are intended to be viewed at certain scales (generally 1:24,000 or 1:25,000) due to accuracy levels. NH GRANIT maintains a continuing program to identify and correct errors in these data but make no claims as to the validity or reliability or to any implied uses of these datasets. As a result, the data presented herein should be used for planning purposes only. If greater data precision is required, this report should be supplemented with field surveys or other on-the-ground methods of data collection. There may also be minor data discrepancies throughout this document due to the variety of source materials and mapping standards used. The reader is encouraged to refer to the original referenced sources if specific data inconsistencies need to be resolved.

Note also that building density is difficult to predict with precision because the exact siting of construction and development occurs in a somewhat unpredictable fashion. A wide range of factors can decrease the permitted density: stormwater drainage facilities, parcel contiguity, ROWs, setbacks, road frontage, conservation restrictions, etc. A standard approach to account for these density losses is to apply an "efficiency factor" to the analysis, which is a simple multiplier that adjusts the "lot efficiency," the amount of land on a parcel that is available for construction after addressing all constraints. Simply stated, an efficiency factor is used to

Table 2-3. Zoning standards for the five municipalities in the Lake Auburn watershed.

Zone	Front Setback (ft)	Side/Rear Set-back (ft)	Minimum Lot Size (sq. ft)	Minimum Lot Size (acres)
Auburn				
Agriculture and Resource Protection	25	15	435,600	10
General Business	25	25	10,000	0.23
Low Density Country Residential	50	15	130,680	3
Neighborhood Business	25	25	0	0
Rural Residential	25	15	43,560	1
Suburan Residential	25	15	21,780	0.5
Turner				
Commercial I	15	5	40,000	0.92
General Residential I	70	25	40,000	0.92
General Residential II	70	25	80,000	1.84
Rural I	25	10	80,000	1.84
Rural II	25	10	217,800	5
Shoreland Zone	35	25	80,000	1.84
Resource Protection	70	25	80,000	1.84
Minot				
Rural District	55	15	108,900	2.5
Hebron				
General Development	35	35	120,000	2.75
Buckfield				
General Development	25	25	40,000	0.92

account for information that can only be obtained upon on-the-ground inspection of particular parcels. Efficiency factors are entered as a percentage, where 100% means complete efficiency (no density lost) and 0% means no buildings are estimated for a zone. FBE used an efficiency factor of 66% for all zones based on prior experience.

The buildout analysis showed that 37% (3,610 acres) of the watershed is buildable under current zoning (1,282 acres or 13% are located within the Auburn portion of the watershed) (Figure 2-4). The greatest acreages of land available for development include the Agriculture and Resource Protection Zone in Auburn (929 acres), the Rural I Zone in Turner (914 acres), the Rural II Zone in Turner (527 acres), and the Rural District in Minot (414 acres). We identified 678 existing buildings within the watershed (419 are in Auburn), and the buildout analysis projected that an additional 938 buildings could be constructed in the watershed in the future (239 would be in Auburn), resulting in a total of 1,616 buildings in the watershed (658 would be in Auburn) (Figure 2-5).

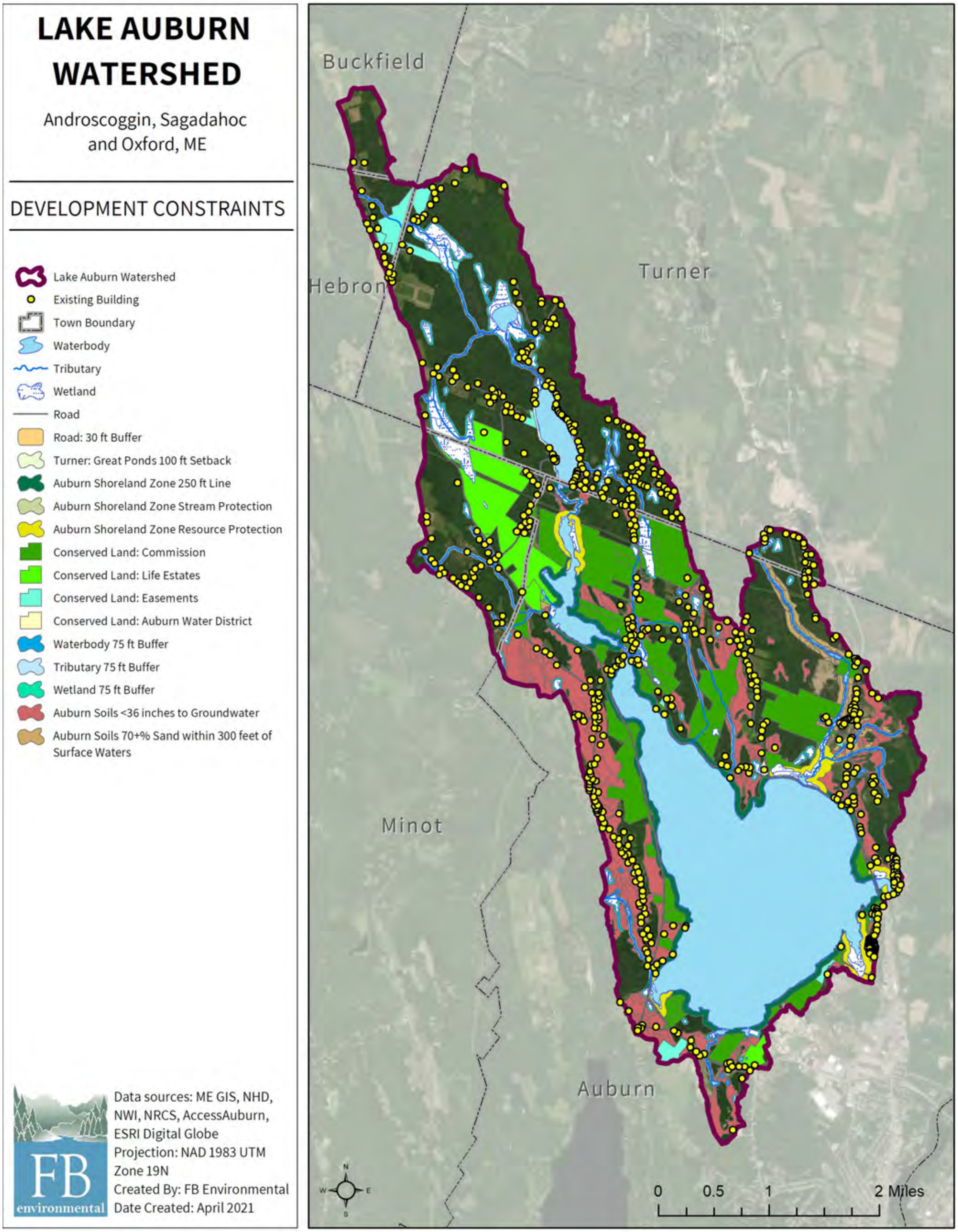

Figure 2-3. Development constraints used in the buildout analysis for the Lake Auburn watershed.

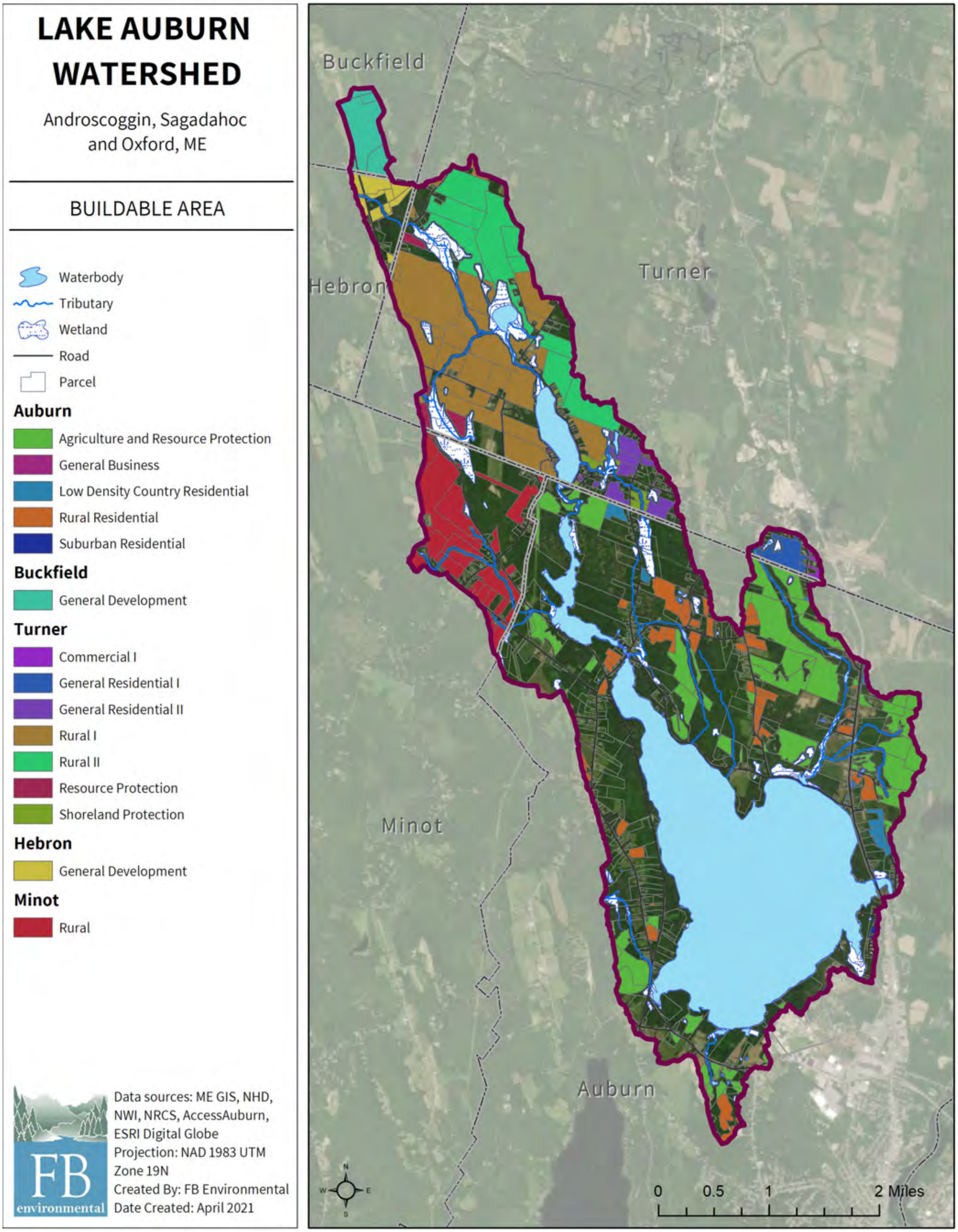

Figure 2-4. Total buildable area by zone determined from the buildout analysis for the Lake Auburn watershed.

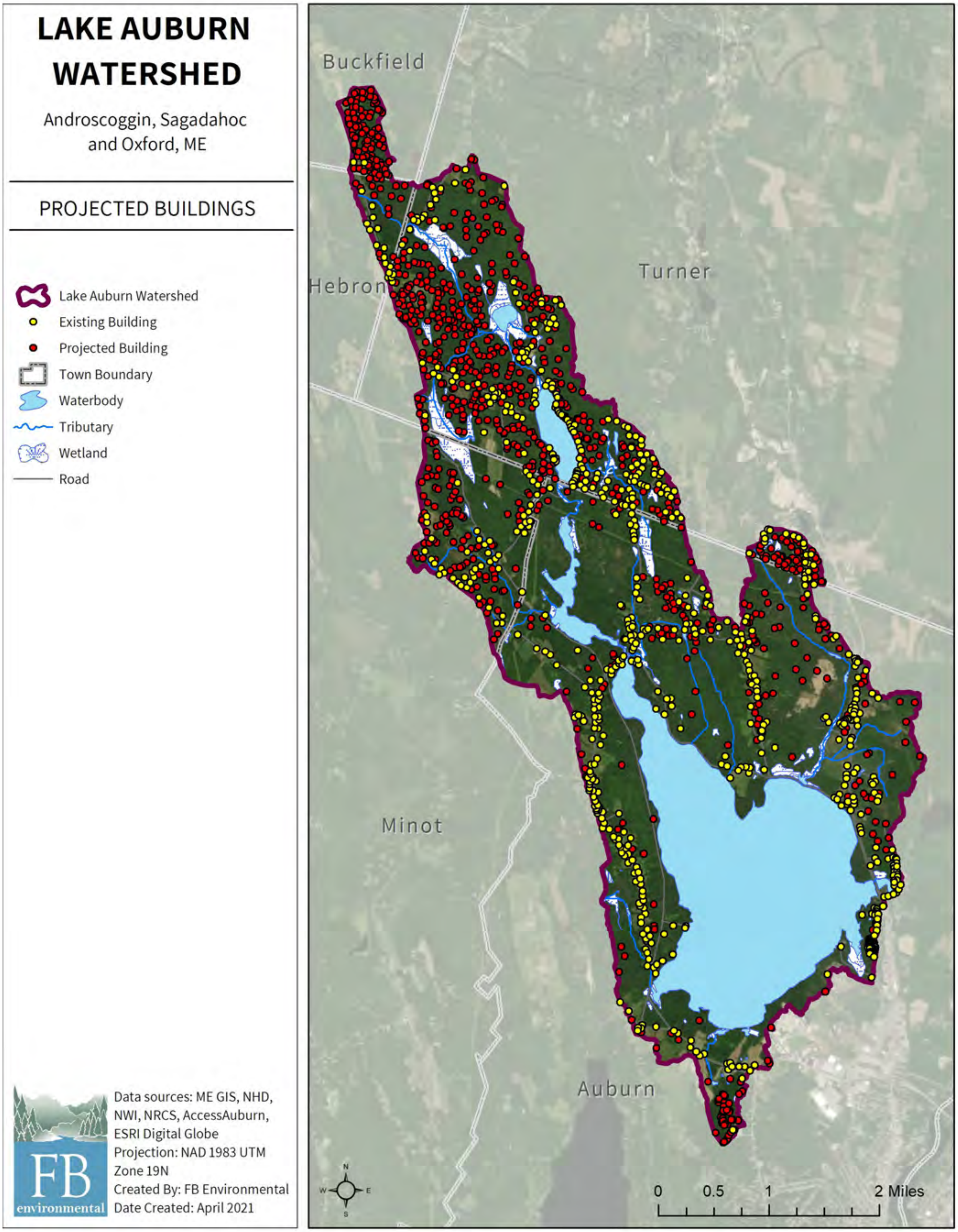

Figure 2-5. Existing (yellow) and projected (red) buildings determined from the buildout analysis for the Lake Auburn watershed.

3 Analysis of Environmental Impacts

This section analyzes the environmental impact of various development and water quality scenarios for the Lake Auburn watershed. The analysis uses a well-documented watershed model paired with in-lake empirical formulas to predict water quality outcomes under each future scenario. This section also reviews recreational threats and opportunities, current forestry practices, and LAWPC's land conservation strategy.

Photo Credit: Sun Journal

Water Quality Modeling

Boundary Change

Based on hydrogeologic studies (E.C. Jordan Co., 1990; Woodard & Curran, 1995; Summit Environmental Consultants, Inc., 2007) of the sand and gravel operations and former City of Auburn landfill along Gracelawn Road, a portion of the existing watershed area was determined to flow away from Lake Auburn in a southerly and easterly direction (Figure 3-1). Groundwater flow studies around the sand and gravel operations showed groundwater flowing south to an unnamed brook in a ravine just south of Mt. Auburn Avenue that flows to the Androscoggin River. Previous analyses of groundwater monitoring well data around the landfill showed low and diminishing levels of leachate indicators on the lakeside compared to increasing levels on the south side away from the lake. The combined properties with sand and gravel operations owned by CLH & Sons, Inc. and Get Er Done, LLC cover 115 acres in the southern portion of the Lake Auburn watershed and are bounded to the north by Lake Auburn and a LAWPC-owned parcel, to the east by a Central Maine Community College-owned parcel, to the south by Gracelawn Road, and to the west by a LAWPC-owned parcel. Based on review of the groundwater contours and 2-ft surface contours, the proposed watershed boundary reduces the watershed area by 148 acres, possibly reducing the original CEI, Inc. (2010) total phosphorus load to Lake Auburn by about 44 kg/yr.

Baseline Model Run

The baseline or "existing conditions" model run was performed using the revised version of the ArcView Generalized Watershed Loading Function (AVGWLF): MapWindow Version 4.6.602 and MapShed Version 1.5.1, available online through the Stroud Water Research Center's WikiWatershed. Following MapShed documentation, model files were prepared for input and processing to generate watershed nutrient loading estimates by sub-basin. These sub-basin nutrient loading estimates were run through a simplified version of the Lake Loading Response Model (LLRM) (AECOM, 2009) to account for sub-basin water and nutrient load attenuation, other water and/or nutrient sources such as atmospheric deposition, internal loading, and septic systems, and in-lake factors such as pan evaporation and annual withdrawal for drinking water. The net water and nutrient loads, along with calculated lake characteristics, were used in several well-known empirical formulas to estimate the in-lake total phosphorus concentration of Lake Auburn.

A summary of inputs and assumptions is provided below. Refer to supplemental model documentation for more detail (available through the City of Auburn).

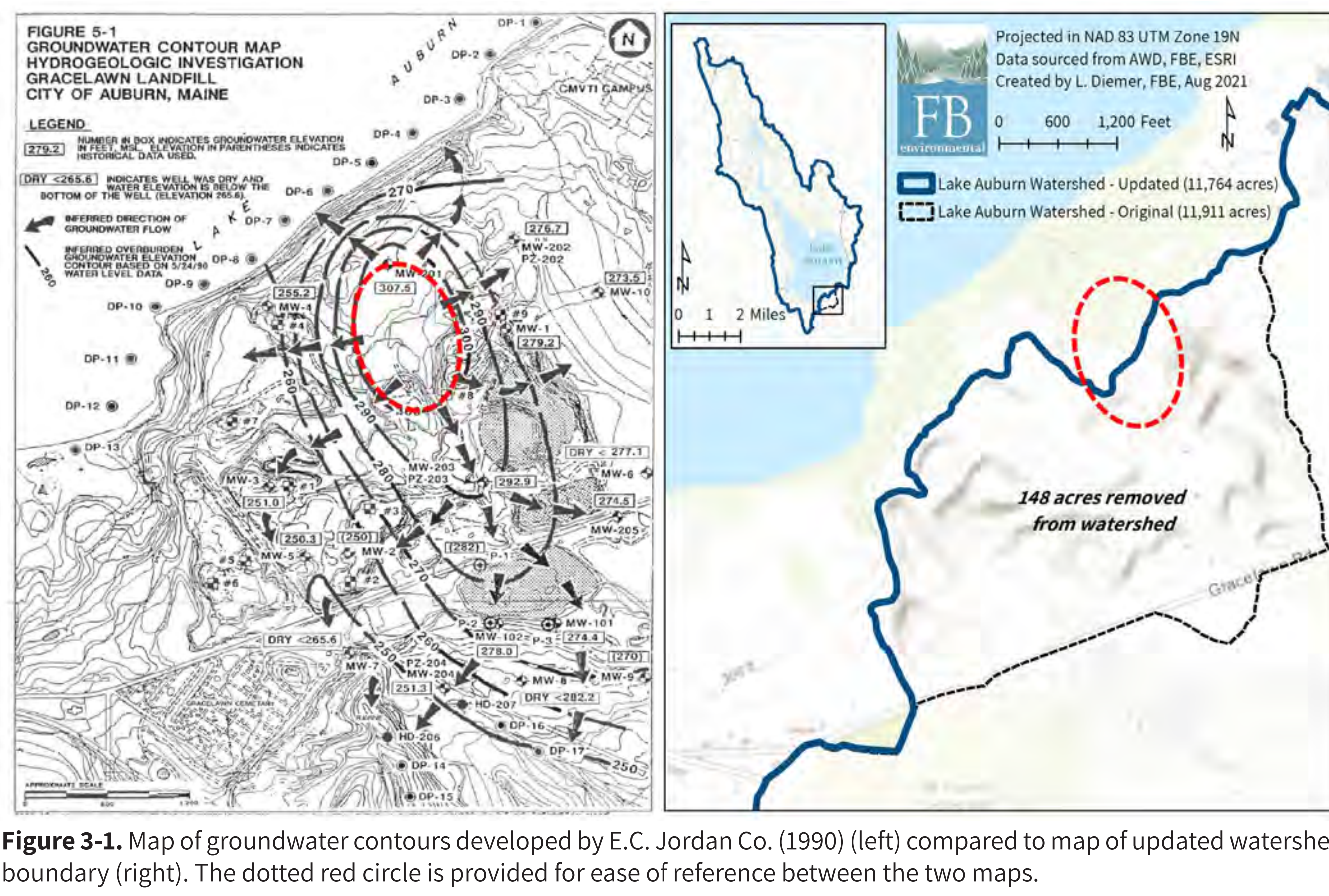

Figure 3-1. Map of groundwater contours developed by E.C. Jordan Co. (1990) (left) compared to map of updated watershed boundary (right). The dotted red circle is provided for ease of reference between the two maps.

Spatial files were prepared for loading into MapShed (all files were projected in NAD 1983 UTM Zone 19N):

Weather station locations (points) and daily precipitation and air temperature (csv): 2011-2020 data were obtained from NOAA National Centers for Environmental Information (NCEI) for weather stations nearest to Lake Auburn. Used LEWISTON, ME US (USC00174566) as the primary data source (63%) and filled in gaps with data from POLAND, ME US (USC00176856) (37%), DURHAM, ME US (USC00172048) (<1%), AUBURN 2.5 NNE, ME US (US1MEAN0012) (<1%), and AUBURN 1.1 NNE, ME US (US1MEAN0026) (<1%).

Sub-basins (polygons): The original CEI, Inc. (2010) sub-basin file contained thirteen sub-basins. MapShed produced a processing error (and crash) when all thirteen sub-basins were selected. MapShed processing is limited by small sub-basins <250 hectares (approx. 1 square mile), of which there were several in the Lake Auburn watershed. To fix the processing error, sub-basins of West Auburn Rd, Youngs Corner, Summer Street, and Gracelawn were combined into a single sub-basin (all located in the southwestern direct discharge area to the lake. Additionally, 148 acres of the original watershed area around Gracelawn Rd area was excluded due to hydrogeologic studies showing groundwater flowing away from the lake (see Boundary Change description above). Excluded filled wetland area in southwest corner of lake from total lake area. Adjusted sub-basin area around the outlet to exclude the lake surface area downstream of the road crossing. The final file used ten (10) sub-basins: Mud Pond (1), Little Wilson Pond (2), The Basin (3), North Auburn Rd (8), Spring Road (7), Lake Shore Drive West (9), Lake Shore Drive East (10), Townsend Brook (4), Route 4 (5), West Auburn Road-Youngs Corner-Summer Street-Gracelawn (6). Excludes the surface area of Lake Auburn.

Streams (polylines): Used a stream network file provided in the documentation for MapShed/NEIWPCC NY/NE Section 8 (2012). Matched well with recent National Hydrography Dataset (NHD) files.

Unpaved Roads (lines): Extracted unpaved roads from MEGIS road layer (NGRoads.shp). Features are treated as "non-vegetated" surfaces, similar to disturbed areas and cultivated land that transport additional sediment and nutrients.

Counties (polygons): Used county boundaries provided by MapShed/NEIWPCC NY/NE Section 8 (2012) with estimates of cropping management (C) and erosion control practice (P) factors for different land cover types for use in the Universal Soil Loss Equation (USLE). Data are used to adjust default values for cropland, hay/pasture, and forest land uses. Updated C_CROP and P1-P5 columns with Model My Watershed average estimate for the entire watershed: C Factor for Cropland = 0.429; P Factor for Cropland = 0.944. Kept C_PAST and C_WOOD as default. Personal communication with the model developer, Dr. Barry Evans, indicated that the Model My Watershed online application utilizes more updated input data.

Soils (polygons): Used for mapping the spatial variability of soil water-holding capacity, soil erodibility, and Hydrologic Soil Groups (HSGs) A, B, C, D to determine permeability of soils and thus runoff coefficients for different land use types. The watershed area extracted from NRCS Web Soil Survey (WSS) contained more than one soil survey area from the Androscoggin/Sagadahoc and Oxford counties. Oxford County includes the small portion of the watershed in Buckfield and Hebron. These two survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries. WSS notes that both soil survey areas were last updated on June 1, 2020. For dual HSG designations, FBE manually reviewed each polygon with aerials and the National Wetland Inventory (NWI) layer. Any dual HSG designated polygons in clear wetland areas were relabeled as "D." All other areas were relabeled with their drained designation - "A", "B", or "C". Water holding capacity was multiplied by the total soil depth for each soil series.

Physiographic Provinces (polygons): Contains hydrologic parameter data (polygons) for groundwater recession rate and erosivity coefficients (warm/cool seasons) provided by MapShed/NEIWPCC NY/NE Section 8 (2012).

Land Use (raster): Maine Land Cover Database (MELCD) (2001) (converted raster to feature polygon) was merged with the City of Auburn's Land Cover feature layer (2013, updated in 2018), with significant modifications by FBE based on recent aerial imagery (7/19/19) and union of updated feature layers for roads (MEGIS, NGRoads.shp, a 25 ft buffer around roads was added as low-density mixed urban), buildings (City of Auburn, Buildings.shp, added as low-density residential), wetlands (NWI Mapper for emergent, shrub wetlands, no forested wetlands, ponds, lakes, and rivers, added as water), and streams (NHDFlowline.shp, 15 ft buffer around streams was added as water). Land cover categories were matched to the model's 15 input categories (wetlands were combined with water). Removed surface area of Lake Auburn. Final land cover file clipped to watershed extent and converted to raster. Grid cell values correspond to specific land use coding used by the model (see definitions in MapShed documentation). Grid cell size 10x10 meters.

Elevation (raster): Used a digital elevation model (DEM) 30-meter elevation grid provided by MapShed/NEIWPCC NY/NE Section 8 (2012). Data were used to calculate land slope-related parameters.

Groundwater Nitrogen (raster): Used background estimate of nitrogen (N) in mg/L in groundwater (shallow subsurface flow) provided by MapShed/NEIWPCC NY/NE Section 8 (2012).

Soil Phosphorus (raster): Estimate of soil phosphorus (P) in mg/kg (total soil P) provided by MapShed/NEIWPCC NY/NE Section 8 (2012).

Once the source file was loaded, all ten sub-basins were selected, and model run assumptions were selected using the Create GWLF Input function:

Weather Years: Selected 2011-2020 as the critical period of interest. Climatic outliers were considered and identified as years with Standardized Precipitation Index (SPI) values less than -1.5 or more than 1.5 (based on an average of recent 30 years of data from local weather stations; see full description in McKee et al., 1993). Obtained precipitation data from the nearest weather stations for the prior 30 years. Calculated the average annual total precipitation and the standard deviation for the dataset. For each year in the 10-year critical period of interest (2011-2020), calculated the difference of total precipitation from the 30-year average and divided by the 30-year standard deviation. Matched values with ranges associated with nuanced conditions defined as follows: 2.0 or more = extremely wet, 1.5 to 1.99 = severely wet, 1.0 to 1.49 = moderately wet, -0.99-0.99 = near normal, -1.0 to -1.49 = moderately dry, -1.5 to -1.99 = severely dry, -2.0 or less = extremely dry. From 2011-2020, two years (2011, 2014) were identified as moderately wet, one year (2012) as severely wet, and the remaining seven years as near normal. The year 2012 was identified as a climatic outlier but was kept in the 10-year average for model calibration because of the robust water quality data available from 2011-2020. Average annual precipitation by decade was calculated as 43.73 inches from 1991-2000, 47.80 inches from 2001-2010, and 49.37 inches from 2011-2020 and showed generally wetter conditions with each decade.

Growing Season: selected May-October.

Aggregate Basins: checked No.

LS Method: checked Flow Accumulation.

The model generated individual run files for each sub-basin, which were manually edited and then run for 10 years using the Run GWLF-E Option:

Livestock Estimates: Livestock estimates were derived from Model My Watershed, which obtains county-level farm animal population data available from the United States Department of Agriculture (USDA) and weights by "farmland acres" for each sub-basin. MapShed uses a set of algorithms to simulate nutrient loading from livestock. It considers monthly time spent grazing, at pasture, direct access to stream, daily accumulation on the landscape, runoff to streams based on daily weather conditions, and certain livestock and agricultural practices such as plowing manure into the soil and manure management plans. It is important to note that the model treats all manure produced in the watershed as remaining in the watershed in some form. The model does not directly include a mechanism for manure export out of or import into the watershed. For example, a watershed containing a large farm which produces and sells liquid manure from its livestock would probably experience lower nutrient loading in reality than what the model predicts, since much of the manure is shipped out of the drainage area. Conversely, large farms which import manure onto their fields from outside the watersheds could result in higher nutrient loading to streams than the model predicts.

The model output by sub-basin for water and nutrient loads were input to a simplified LLRM. Additional water and nutrient sources or factors were estimated:

Direct Atmospheric Deposition: The lake surface area (930 hectares) was multiplied by a median coefficient for phosphorus entering the lake as atmospheric deposition (0.20 kg P/ha/yr). For largely forested areas, a minimum of 0.07 kg P/ha/yr and a maximum of 0.54 kg P/ha/yr are suggested, with a median value of 0.20 kg P/ha/yr (Reckhow et al. 1980, Dillon et al. 1991). Schloss et al. (2013) calculated a coefficient of 0.11 kg P/ha/yr for a rural, forested watershed in New Hampshire. Lake Auburn is located near an urban area, but prevailing winds come from rural, forested areas in Maine. CEI, Inc. (2010) used a coefficient of 0.22 kg P/ha/yr and a surface area of 914 hectares.

Internal Phosphorus Loading: Similar procedures to CEI, Inc. (2010) were used to estimate internal phosphorus loading. The hypolimnion was identified as starting at 15 meters and deeper, which represents 16% of the total water volume. The difference between total phosphorus concentration measured in the epilimnion and hypolimnion was calculated for each collection day. The average of the maximum difference in each year from 2011-2020 was determined, excluding 2011 (no September data) and 2019/2020 (year during or following alum treatment), and multiplied by the hypolimnion volume to generate a total load estimate derived from internal load. The estimation matched well with CEI, Inc. (2010) estimation, indicating little change in internal loading (up until the 2019 alum treatment).

Septic Systems: Used number of persons per dwelling based on US Census data for 2015-2019 for Auburn and Turner (average = 2.325) and 0.7 kg of phosphorus contributed by each person on average (Metcalf & Eddy, 1991 and CEI, Inc., 2010) to estimate the total septic system load. A soil retention coefficient of 0.8 (per the 1987 Watershed Management Study and CEI, Inc., 2010) was applied to the total septic system load (which equates to an attenuation factor of 0.2). Septic systems within 300 ft of a surface water other than the lake were added to the total load for each sub-basin (which account for additional attenuation). Septic systems within 300 ft of the lake were calculated separately and included as a direct source to the lake. Input assumptions and calculations matched well with CEI, Inc. (2010), except an attenuation factor of 0.8 was used by CEI, Inc. (2010) instead of 0.2. Because of this difference in assumption (80% vs. 20% phosphorus retained in the soil), it is likely that the CEI, Inc. (2010) septic system load estimate was overestimated.

<u>Pan Evaporation</u>: Matched the evaporation rate of 23.15 inches used by CEI, Inc. (2010).

<u>Withdrawal</u>: The average of total annual withdrawal from Lake Auburn (2011-2019, 2020 incomplete at time of analysis) was calculated at 9,206,646 cubic meters per year, which represents 31% of the total annual water load to the lake and 8% of the total lake volume. The water extracted also contains phosphorus. Multiplied the average annual in-lake concentration (10.9 ppb) by the volume of withdrawn water to generate a total phosphorus load estimate (100 kg/yr). Nearly all residents who receive water are outside the watershed and so a negligible amount of withdrawn water returns to the lake. Withdrawal demand has also decreased in the last decade. CEI, Inc. (2010) did not account for withdrawn phosphorus load in the in-lake concentration prediction. Including consideration for withdrawn water and phosphorus load impacts the total annual load estimate and the flushing rate but not the average annual in-lake total phosphorus concentration. The total annual load estimate was reduced by 100 kg/yr (8% decrease) and the flushing rate decreased by every 4 years to every 7 years. Longer flushing rates increase the residence time of water and nutrients in the lake, which can allow more nutrients to settle out to the bottom (building up the legacy phosphorus source) rather than be exported downstream. On the other hand, longer flushing rates mean that it will take longer for the lake to build the in-lake total phosphorus concentration back up to pre partial alum treatment conditions, thereby increasing the estimated efficacy of the treatment. However, we kept the original estimate of 10 years for the partial alum treatment when considering variability with climate change (refer to Alum Treatment in Model Scenarios for further discussion).

The watershed load from the sub-basins was then calibrated:

<u>Streamflow</u>: Model calibration followed guidelines set by Donigian (2002): percent differences between predicted and observed values of < 15% were considered very good (acceptable). Six discharge stations with observed data (n = 37-80 from 2011-2020) were matched with six of the ten sub-basin annual flow predictions. A nearby USGS gaging station (USGS01055500 Nezinscot River at Turner Center, Maine) was used to obtain daily discharge data adjusted to account for drainage area differences for each discharge station. Predicted and observed discharge for each discharge station matched well for most stations to justify the reasonableness of this approach. From the adjusted daily discharge for each discharge station, an average annual water load was estimated. The average annual water load was further adjusted to match the sub-basin drainage area used in the calibration process (since discharge station locations did not always match perfectly with sub-basin outlets). The predicted average annual water load for the six sub-basins fell within 3-11% of the adjusted observed average annual water load, except for The Basin sub-basin at 49% (due to the retention influence of the upstream ponds). The USGS (2004) measured streamflow at three locations in the watershed to establish a water budget for Lake Auburn. CEI, Inc. (2010) used Townsend Brook streamflow measurements to calibrate modeled flows. CEI, Inc. (2010) average annual water load was 18% higher than the USGS (2004) estimate, matching with a 19% increase in average annual precipitation between the two time periods. Our average annual water load was 10% higher than the CEI, Inc. (2010) estimate, matching with a 12% increase in average annual precipitation between the two time periods.

<u>Total Phosphorus Concentration by Sub-Basin</u>: Total phosphorus concentration data from tributaries were compiled into a single database for summation. Six sampling stations (same as the discharge stations except for station #13 which measured discharge upstream of the road crossing and sampled downstream where another incoming tributary likely mixes in) were selected and matched to the closest sub-basin. Concentration-discharge relationships were generated for each station and showed weak correlations for all except station #13 downstream of The Basin outlet. A simple flow-weighted average concentration method (#2) described by Walker (1999) was used. Because sub-basin drainage areas did not match station drainage areas (and drainage area ratio adjustments cannot be made to concentration data), model calibration was not sufficiently performed. Flow-weighted average total phosphorus concentrations were used as guideposts but did not define the calibration process.

<u>Water and Phosphorus Attenuation</u>: Default attenuation values for water (0.95) and phosphorus (0.90) were used (based on the LLRM manual, refer to AECOM, 2009) for all sub-basins to start. Further adjustments were made based on the influence of large wetlands or ponds or long stream reaches that would increase water and nutrient attenuation. Water attenuation for sub-basin #9 was changed to 0.60 to better match observed flow; GWLF-E overestimated average annual water load, which was confirmed by a separate loading coefficient exercise in the LLRM). Due to longer stream reaches and the presence of wetland features in sub-basin #4, the attenuation

factors for water and phosphorus were reduced to 0.90 and 0.80, respectively. Due to the presence of two ponds in sub-basins #2 and #3, the attenuation factors for both water and phosphorus were reduced to 0.50 for sub-basin #3. The water and phosphorus loads from sub-basins #1 and #2 were added to sub-basin #3 before attenuation was applied.

The total water and phosphorus load to Lake Auburn was used as the primary input (among others such as lake characteristics) to several empirical formulas for predicting average annual in-lake total phosphorus concentration.

Observed Total Phosphorus Outflow Concentration: Method (#2) described by Walker (1999) was used to estimate a flow-weighted average concentration for the outlet of Lake Auburn.

Lake Area: A lake area of 2,298 acres was estimated from the land use file (by manually delineating the shoreline based on aerials). 2,260 acres used by USGS (2004) and CEI, Inc. (2010) and 2,248 acres from University of Maine at Farmington (UMF)/AWD bathymetry file.

Lake Volume: UMF conducted depth measurements in 2001 (exact day/month unknown) for the bathymetry file provided by AWD. The average lake elevation during the "boating season" from May-October when the UMF survey was likely completed was 259.37 ft (but ranged from 257.9-261.0 ft). The average year-round lake elevation from 2011-2020 was 260.49 ft, a 1.12-ft difference (but ranged from -0.5-2.6 ft). This difference in water level equates to a lake volume from 2011-2020 of 3,937 million cubic feet (more in line with the USGS (2004) estimate at 3,920 million cubic feet and ultimately used for the model), ranging from 3,417-4,413 million cubic feet. Using the UMF 2001 data provided by AWD, CEI, Inc. (2010) calculated a lake volume of 3,570 million cubic feet, while we calculated a lake volume of 3,577 million cubic feet. CEI, Inc (2010) used the USGS (2004) volume estimate for estimating flushing rate and thus for the Reckhow General 1977 in-lake P prediction. As a sensitivity analysis, adjusting lake volume from 3,577 to 3,937 million cubic feet dilutes the in-lake total phosphorus concentration by 0.3 ppb.

Observed In-Lake Total Phosphorus Concentration: Water quality data (total phosphorus, chlorophyll-a, Secchi disk transparency) were summarized (median or mean) by day for upper depths (epilimnion or upper 10 meters if unstratified), then by month, by year, and by all years for calibration. The average annual in-lake total phosphorus concentration of 10.9 ppb was used for model calibration. CEI, Inc. (2010) used 10.3 ppb for model calibration.

Empirical Formulas: Averaged three empirical lake models: Kirchner-Dillion 1975, Jones-Bachmann 1976, and Reckhow General 1977. Predicted in-lake total phosphorus concentration of 10.9 ppb compared to an observed in-lake total phosphorus concentration of 10.9 ppb. Jones-Bachmann 1976 predicted current lake conditions the best, but it is recommended to take the average of multiple empirical formulas especially when projecting into the future under uncertain circumstances.

Model Scenarios

With the calibrated model for baseline or "existing conditions," we were able to run multiple scenarios that changed certain underlying assumptions and predicted future lake water quality conditions. Several model scenarios were run:

1. Baseline + Alum Treatment
2. Baseline + Alum Treatment + Climate Change (Representative Concentration Pathways (RCP) 4.5)
3. Baseline + Alum Treatment + Climate Change (RCP 8.5)
4. Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "Business As Usual" Buildout (No Code Changes)
5. Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "Maximum Development Not Allowing Building on LAWPC Lands" Buildout (Codes Relaxed, LAWPC Lands Remain Protected)
6. Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "Maximum Development Allowing Building on LAWPC Lands" Buildout (Codes Relaxed, LAWPC Lands Open for Development)
7. Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "Business As Usual" Buildout (No Code Changes) + Low Impact Development Standards
8. Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "Maximum Development Not Allowing Building on LAWPC Lands" Buildout (Codes Relaxed, LAWPC Lands Remain Protected) + Low Impact Development Standards
9. Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "Maximum Development Allowing Building on LAWPC Lands" Buildout (Codes Relaxed, LAWPC Lands Open for Development) + Low Impact Development Standards

Alum Treatment: A partial alum treatment in 2019 resulted in a 78% reduction in internal phosphorus loading (from 373 kg/yr (31%) to 83 kg/yr (9%)). We applied this reduction to all future scenarios, assuming for simplicity that in-lake treatments will continue at regular intervals indefinitely to curb the internal phosphorus load and reset the in-lake total phosphorus concentration to less than 10 ppb.

However, watershed management efforts to reduce phosphorus sources before entering Lake Auburn should continue to be the first component of LAWPC's long-term protection strategy. According to WRS, Inc. (2019) and personal communication with Dr. Ken Wagner, the original intent of the partial alum treatment in 2019 was to reset the lake back to a lower in-lake total phosphorus level to buy additional time for continued watershed management efforts. If watershed management efforts are insufficient and phosphorus builds back up in the lake to levels that trigger blooms, then an alum treatment may be considered again to strip the water column of phosphorus and inactivate bottom phosphorus loading. However, the future decision to utilize another alum treatment as an in-lake treatment option should be based on a nuanced review of additional data and the best available technology at that time, as well as the primary source of phosphorus (i.e., external versus internal) causing degraded water quality. For instance, the 2012 bloom was triggered by high internal phosphorus load during an abnormally warm and long growing season that greatly expanded the extent and duration of anoxia throughout the lake. Conversely, the 2018 bloom was triggered by a series of major storms sending large amounts of phosphorus from the watershed to the lake, while anoxic extent and internal phosphorus load were much lower compared to 2012. The decision to perform repeated alum treatments in the future will depend on the efficacy of the first partial dose in 2019 and whether future blooms are driven more by internal or external sources. Consecutive years with high external loading of phosphorus would make alum treatments less effective, both economically and environmentally.

With only one full year post-treatment, there are currently insufficient data to determine the long-term efficacy of the partial alum treatment in 2019. Personal communication with Dr. Holly Ewing of Bates College indicated that the alum treatment was holding in summer 2021; however, July 2021 saw exceptionally large amounts of rainfall in the area, likely sending equally large amounts of phosphorus load to the lake, especially from Townsend Brook, which may drive blooms in early fall. Consecutive years with abnormally high precipitation such as occurred in 2021 will build up phosphorus in the water faster and reduce the longevity of the treatment. Fortunately, Lake Auburn experiences a long residence time, meaning that it takes several years for enough water to enter Lake Auburn to completely refill its volume; this also means that it will take several years for enough phosphorus to enter Lake Auburn to build up the in-lake total phosphorus concentration.

Dr. Ken Wagner recommended that sediment samples be collected from Lake Auburn after 5 years (2024) to analyze the availability of key elements, namely phosphorus, aluminum, and iron, and assess the efficacy of the treatment. WRS, Inc. (2019) alternatively recommended that aluminum dosing stations could be set up near the outlets of the two major tributaries to Lake Auburn: the Basin Stream and Townsend Brook. Stormwater flows could be treated with 1 mg/L of polyaluminum chloride to strip phosphorus from the water before entering Lake Auburn. The installation cost would be <$100,000 for each station and cost about $40,000 annually to maintain. Personal communication with Dr. Ken Wagner indicated that the amount of chloride used in the dosing would have negligible impact to the concentration of chloride in the lake and would have a preferably lesser impact compared to alternative compounds such as aluminum sulfate. Dr. Ken Wagner also indicated similarly that alum treatments within the lake do not significantly increase conductivity (or chloride concentration) in the lake, the highest doses (many times that which was applied to Lake Auburn) having only raised conductivity by 40 µS/cm in other lakes. Even so, chloride can be disruptive to biota and lake stratification, so the potential impacts that chloride can have on lake ecosystems should not be minimized. Chloride and conductivity testing should be expanded as part of the water quality monitoring program if additional treatments are used, and any use of deicing salt, which contains chloride, on roads or parking areas (both private and public) in the watershed should be reviewed. Although there are risks, when applied with skill and caution, alum treatment is considered a safe and cost-effective means of internal phosphorus load reduction (refer to CDM Smith, 2014 for a more detailed discussion of the benefits and potential drawbacks of alum treatments).

Climate Change: To simulate future climate change in the lake water quality model, we used the NOAA Climate Explorer for the Auburn, ME area to obtain monthly total precipitation and maximum/minimum air temperature predictions under two emissions scenarios from the RCP (Representative Concentration Pathways) 4.5 and 8.5, part of the Coupled Model Intercomparison Project Version 5 (CMIP5). Fernandez et al. (2020) identifies the RCP 4.5 emission scenario as moderate but most other literature identifies it as low. The RCP 8.5 emission scenario is considered the "business as usual" higher emission scenario based on an unlikely future of increasing coal reliance. Although the RCP 8.5 emission scenario may overpredict future climate change, most sources cite it as still a relevant and plausible future outcome to consider (MCC STS, 2020; Schwalm et al., 2020).

For this study, we considered both the RCP 4.5 and 8.5 emission scenarios for the Auburn, ME area to best capture possible future conditions in Lake Auburn. Total annual precipitation is projected to increase by 6% and

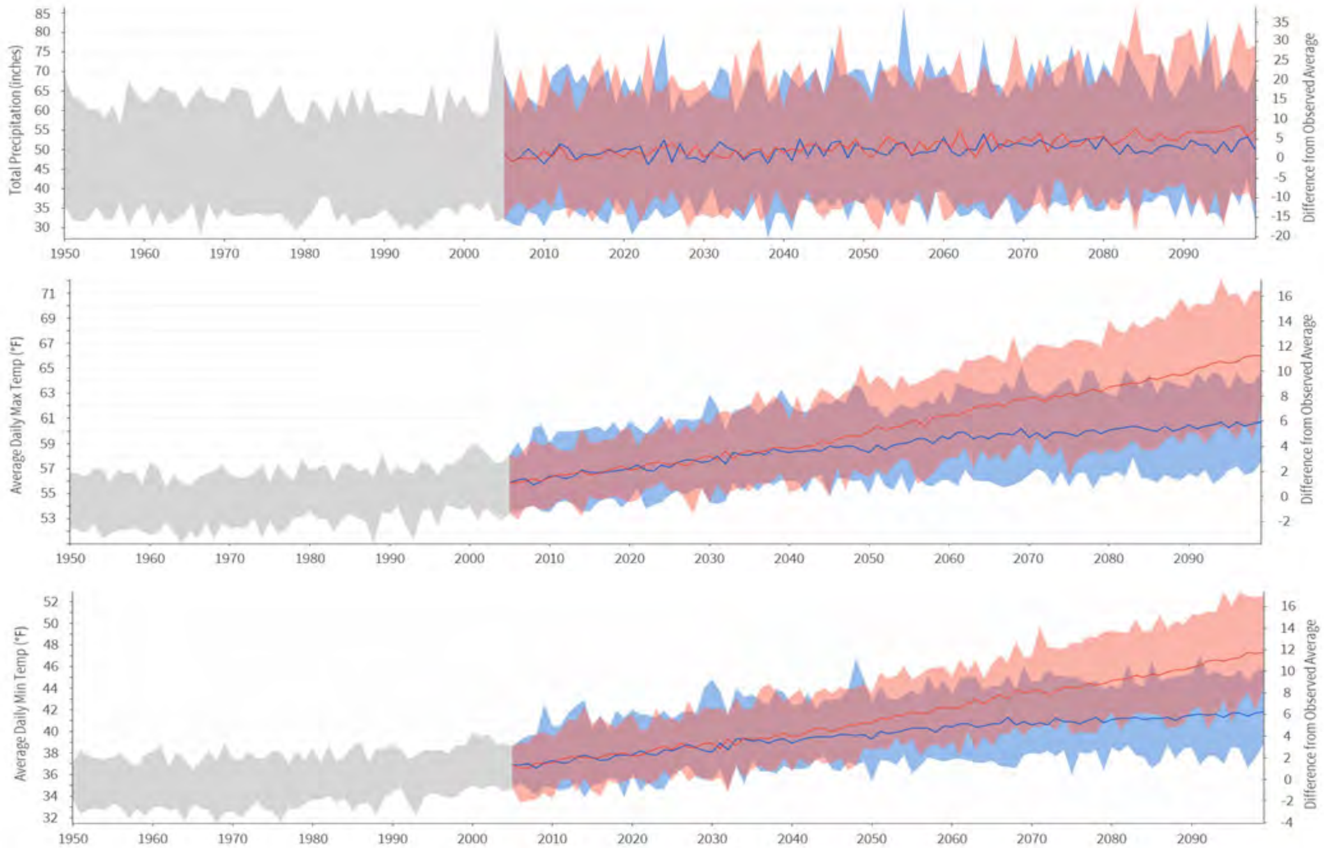

Figure 3-2. Historical observed (dark gray) and modeled (light gray), as well as projected higher (RCP 8.5, red) and lower (RCP 4.5, blue) emissions scenarios for the Auburn, ME area for total precipitation (top), maximum temperature (middle), and minimum temperature (bottom). Chart images obtained from the NOAA Climate Explorer.

10% from 2020-2100 for the RCP 4.5 and 8.5 emission scenarios, respectively. Average maximum temperature is projected to increase 7% (4.1 degrees F) and 15% (8.7 degrees F) from 2020-2100 for the RCP 4.5 and 8.5 emission scenarios, respectively. Average minimum temperature is projected to increase 11% (4.4 degrees F) and 24% (9.0 degrees F) from 2020-2100 for the RCP 4.5 and 8.5 emission scenarios, respectively. These changes are predicted to occur unequally throughout the year with generally wetter, warmer winters and springs and drier, warmer summers and falls (Figure 3-2, Table 3-1).

The impact of climate change on predicted external load for either emission scenario was minimal, so subsequent model scenarios incorporated only the RCP 4.5 emission scenario.

Future Buildouts: Refer to Land Use History & Development Pressures section for a description of the methodology employed for conducting the "Business As Usual" buildout, which represents no code changes to existing zoning standards. We assumed all current zoning and lake protection ordinances remained unchanged, and development proceeded in a business-as-usual manner. Additional buildout scenarios were run to generate new estimates of projected buildings, as described below.

"Maximum Development Not Allowing Building on LAWPC Lands": The following changes were made for this scenario (otherwise assumptions and inputs followed the "Business As Usual" buildout):

- Three village nodes were created with 51 parcels in Auburn rezoned:
  - » East Auburn: Parcels along Oak Hill Road and Andrew Drive (except for East Auburn Community School) were rezoned to be Neighborhood Business. There is no minimum lot size, and a sewer connection is assumed.
  - » Townsend Brook Road: Parcels southwest of Townsend Brook Road were rezoned as Neighborhood Business (except for the 228-acre parcel 391-001 which remained as Agriculture and Resource Protection due to its size and breadth). There is no minimum lot size, and a sewer connection is assumed.

Table 3-1. Projected change (inches or degrees F and percent) from 2020-2100 in monthly and annual total precipitation, maximum temperature, and minimum temperature for the RCP 4.5 and 8.5 emissions scenarios for the Auburn, ME area (data obtained from the NOAA Climate Explorer).

Month	PRECIPITATION				MAXIMUM TEMPERATURE				MINIMUM TEMPERATURE			
	RCP 4.5 (%)	RCP 4.5 (inches)	RCP 8.5 (%)	RCP 8.5 (inches)	RCP 4.5 (%)	RCP 4.5 (F)	RCP 8.5 (%)	RCP 8.5 (F)	RCP 4.5 (%)	RCP 4.5 (F)	RCP 8.5 (%)	RCP 8.5 (F)
Jan	4%	0.15	24%	0.95	13%	4.02	29%	9.02	42%	5.68	90%	11.67
Feb	16%	0.55	22%	0.78	13%	4.51	22%	7.67	39%	5.66	66%	9.84
Mar	9%	0.43	18%	0.81	9%	3.76	19%	7.86	16%	3.97	34%	8.16
Apr	4%	0.17	18%	0.75	8%	4.28	16%	8.52	12%	4.19	24%	8.47
May	4%	0.15	5%	0.18	6%	4.06	13%	8.58	8%	3.79	18%	8.12
Jun	6%	0.23	1%	0.02	5%	3.93	11%	8.55	7%	3.74	14%	7.90
Jul	7%	0.25	3%	0.11	5%	4.12	11%	9.09	6%	3.87	14%	8.56
Aug	-1%	-0.02	4%	0.15	6%	4.73	13%	10.66	8%	4.51	17%	10.24
Sep	6%	0.22	-4%	-0.15	6%	4.05	13%	9.58	7%	3.79	18%	9.24
Oct	3%	0.14	0%	0.00	7%	4.19	15%	8.86	10%	4.23	21%	8.69
Nov	7%	0.32	8%	0.38	8%	3.68	17%	8.03	12%	3.88	25%	8.00
Dec	6%	0.28	23%	1.07	12%	4.29	24%	8.46	25%	4.95	47%	9.32
Annual	**6%**	**2.87**	**10%**	**5.04**	**7%**	**4.13**	**15%**	**8.74**	**11%**	**4.35**	**24%**	**9.02**

   » North Auburn: Parcels along North Auburn Road from Holbrook Road to Skillings Corner Road were rezoned as General Business. The minimum lot size is 0.23 acres, and no sewer connection is assumed.

- Removed development restrictions on land with less than 36 inches to groundwater and on land with sandy soils within 300 feet of the shoreline. Shoreland Zoning Overlay District with setbacks still applied.

The buildout analysis for this scenario showed that 46% (4,532 acres) of the watershed is buildable under current zoning (2,201 acres or 22% are located with the Auburn portion of the watershed) (Appendix 4). We identified 678 existing buildings within the watershed (419 are in Auburn), and the buildout analysis projected that an additional 1,287 buildings could be constructed in the watershed in the future (587 would be in Auburn), resulting in a total of 1,965 buildings in the watershed (1,006 would be in Auburn) (Appendix 4).

"Maximum Development Allowing Building on LAWPC Lands": Same as "Maximum Development Not Allowing Building on LAWPC Lands" except LAWPC lands were removed from protected status, allowing development to occur on those lands according to their assigned zoning (except for the parcels abutting Outlet Beach and the Outlet Pond east of Route 4, as well as the parcel housing the water treatment plant). Removing protection from LAWPC lands allows for 368 new buildings to be developed in Auburn in the watershed.

The buildout analysis for this scenario showed that 61% (6,008 acres) of the watershed is buildable under current zoning (3,677 acres or 37% are located with the Auburn portion of the watershed) (Appendix 4). We identified 678 existing buildings within the watershed (419 are in Auburn), and the buildout analysis projected that an additional 1,660 buildings could be constructed in the watershed in the future (960 would be in Auburn), resulting in a total of 2,338 buildings in the watershed (1,379 would be in Auburn) (Appendix 4).

The projected buildings output was used to adjust land use, livestock numbers, and septic system numbers in the future scenario model runs to predict changes in in-lake water quality.

- Land Use: We first summarized existing (2020) watershed land use area by town for the 15 land use categories. We divided the area for developed land use types by the number of existing buildings in each town to generate the developed land use area per building. Based on the land use change analysis from 1997-2020, we determined the average rate of net agricultural land loss and projected a similar rate into the future to the point when full buildout is achieved. The number of projected new buildings by sub-basin and town were derived from the buildout analysis and used to estimate the amount of new developed land use at the expense of both agricultural land and forest. Table 3-2 provides a breakdown of changes in major land use categories for each scenario.

- Livestock Numbers: Livestock numbers were adjusted based on the percent loss in agricultural land by sub-basin for each future scenario.
- Septic System Numbers: The number of both existing and new buildings within 300 feet of mapped waterbodies (lakes, ponds, major wetlands, streams) was determined and run through the same equation for deriving the total phosphorus load as described in the Baseline Model Run section.
- Atmospheric deposition was adjusted to reflect more precipitation and more development in the future (used a coefficient of 0.44 kg P/ha/yr). Pan evaporation was adjusted to reflect warmer temperatures under the RCP 4.5 scenario. Both were kept the same among all future scenario model runs.

Low Impact Development: To simulate the effect of implementing low impact development strategies on all new development (in Auburn only), we kept everything the same for each future scenario model run except for the added assumption of low impact development use on new buildings. To account for this in MapShed, we adjusted the land use areas for each sub-basin for the headwater towns (to match the "Business As Usual" scenario) and undeveloped land use types for Auburn (to match each of the three future scenarios) in the Transport Data window. Next, we added new development areas (to match each of the three future scenarios) to the BMP Data window, selected "Infiltration Basin" from the dropdown BMP menu, and entered 2.54 cm for 1-inch rainfall capture. The new development areas were estimated based on projected new buildings but accounted for a 30% reduction in total impacted area per new building. BMPs utilized for each new building were assumed to result in a 70% reduction in total phosphorus export in surface runoff. Table 3-2 provides a breakdown of changes in major land use categories for each scenario.

Before presenting the model scenario results, there are several important assumptions to consider for interpretation:

- The calibrated baseline or "existing conditions" model suggests that the combination of Little Wilson Pond and The Basin has a large nutrient attenuation capacity of about 50%. Nearly all the headwater towns pass through Little Wilson Pond and The Basin, which has important implications for development impact. For example, one new building in the Auburn portion of the watershed has roughly the same impact as two new buildings in the other headwater towns. However, as development (and thus nutrient load) increases over time, the attenuation capacity of the ponds may diminish as they reach a

Table 3-2. Land use area (hectares, ha) and percent cover (%) for baseline or "Existing Conditions", as well as the modeled future scenarios, for the Lake Auburn watershed.

Land Use	Unit	Existing Conditions	Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "**Business As Usual**" Buildout (No Code Changes)	Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "**Maximum Development Not Allowing Building on LAWPC Lands**" Buildout (Codes Relaxed, LAWPC Lands Remain Protected)	Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "**Maximum Development Allowing Building on LAWPC Lands**" Buildout (Codes Relaxed, LAWPC Lands Open for Development)	Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "**Business As Usual**" Buildout (No Code Changes) **+ Low Impact Development Standards**	Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "**Maximum Development Not Allowing Building on LAWPC Lands**" Buildout (Codes Relaxed, LAWPC Lands Remain Protected) **+ Low Impact Development Standards**	Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "**Maximum Development Allowing Building on LAWPC Lands**" Buildout (Codes Relaxed, LAWPC Lands Open for Development) **+ Low Impact Development Standards**
Developed	hectares (ha)	588	1264	1544	1867	1194	1386	1612
Agriculture		241	112	112	112	116	112	112
Forest		2810	2262	1982	1659	2327	2141	1914
Water		185	185	185	185	185	185	185
Developed	percent (%)	15%	33%	40%	49%	31%	36%	42%
Agriculture		6%	3%	3%	3%	3%	3%	3%
Forest		74%	59%	52%	43%	61%	56%	50%
Water		5%	5%	5%	5%	5%	5%	5%

yet undetermined saturation point, and thus, development in the headwater towns may have greater impact to Lake Auburn in the future.

- All buildout scenarios assumed no change in current zoning for the headwater towns. If development ordinances change in those towns to encourage additional growth, then model assumptions and the water quality risk assessment will be different (and possibly worse).

- Land use adjustments assumed that the prior 20-year decline in agricultural lands in the watershed will continue in the future. The model assumes much higher nutrient loads from agricultural lands compared to other developed lands such as residential or commercial, so nutrient loads are reduced with agricultural land conversion to other developed land types until more development accumulates to match the original nutrient load.

- Land use adjustments were changed manually in MapShed after the original 2020 land cover file was loaded into MapShed. MapShed averages factors such as slope by land use category for each sub-basin, so adjusting land use manually applies those same factors when in reality those factors may be altered under varying spatial distributions. Similarly, MapShed accounts only for total development area and not where development occurs within a sub-basin. Changing the locations of buildings and development can worsen environmental impact, for example, by failing to use setback distances from sensitive areas. As a sensitivity analysis, we ran a separate model scenario to account for changes in the spatial distribution of future development and found that predicted in-lake total phosphorus concentration increased by 0.3 ppb, possibly suggesting variability around the predictions of other model scenarios.

- The end point was set at 2100 to match the extent of climate change model scenarios and simplify the buildout pattern assumptions given the large uncertainties around factors controlling future development. However, it is likely that buildout patterns could extend beyond 2100 (given the area's slow population growth). Based on the number of new buildings added to the watershed from 1997-2020, we estimate that full buildout (for the future "Business As Usual" buildout) of projected new buildings in the watershed would occur by 2188.

- Water withdrawal demand has been stagnant or declining in recent decades, and the AWD does not expect considerable increases in demand in the future. We assumed no change in water withdrawal by 2100.

Model Results

The results of the baseline and scenario models are presented in Table 3-4. The partial alum treatment applied in 2019 reset the lake to a much lower total phosphorus load and in-lake concentration. It is anticipated that this partial alum treatment will last 10 years, and it was assumed for simplicity that AWD will continue to apply alum treatment as a method of in-lake total phosphorus load control (see prior discussion under Model Scenarios section for more detail); otherwise, the water quality of Lake Auburn will rapidly deteriorate, especially when compounded by the effects of climate change and increased development in the future.

At an annual scale for the climate-change-only scenario model runs, the in-lake water quality predictions for Lake Auburn showed no net change or slight decrease in nutrient loading and in-lake total phosphorus concentration because the increase in precipitation is countered by an increase in evapotranspiration and earlier snow melt due to warmer air temperatures. Other models for New England lakes also show the possibility of decreasing total phosphorus load under future climate change scenarios (Kalcic et al., 2019; Messina et al., 2020; Huser et al., 2018); though several other models for New England lakes show the opposite trend of increasing total phosphorus load by the end of the century (Stoddard et al., 2016, Farrell et al., 2020). More so, the modeled annual scale does not account for short-term increases in total phosphorus loading that may occur as a result of runoff or mixing during extreme precipitation events coupled with warm air temperatures (Kalcic et al., 2019). Additionally, these simple models, such as used for Lake Auburn, are external watershed loading models that do not account for significant changes to within-lake dynamics that will alter nutrient processing and retention, such as a lengthening stratification period and deepening thermocline. The complexity of lake systems as integrators

> The water quality of Lake Auburn will rapidly deteriorate without controlling for internal phosphorus loading, especially when compounded by the effects of climate change and increased development in the future.

of all the physical, chemical, biological, and atmospheric changes within their watersheds make predictions of future lake conditions challenging, but consensus by the scientific community is that climate change will have major impacts on nutrient processing and blooms in lakes (Moss, 2012).

Under the future "Business As Usual" (no code changes) scenario, total phosphorus load and in-lake concentration increase to 957 kg/yr and 9.5 ppb, respectively. Adjusting for low impact development on new development in the Auburn portion of the watershed (237 new buildings, 70 acres less developed accounting for 30% reduction in development footprint per building, 70% phosphorus export reduction on 233 acres of new developed land) reduces the in-lake total phosphorus concentration minimally by 0.1 ppb. Auburn's new development potential is limited and located away from the direct shoreline area, allowing for natural attenuation of nutrients regardless of low impact development use.

Under the future "Maximum Development Not Allowing Building on LAWPC Lands" (codes relaxed) scenario, total phosphorus load and in-lake concentration increase, the latter of which becomes close to and within the prediction's margin of error to 10 ppb – the threshold for increased bloom risk (see discussion below on Filtration waiver violation & bloom frequency). Adjusting for low impact development on new development in the Auburn portion of the watershed (592 new buildings, 159 acres less developed accounting for 30% reduction in development footprint per building, 70% phosphorus export reduction on 512 acres of new developed land) reduces the in-lake total phosphorus concentration by 0.4 ppb.

Under the future "Maximum Development Allowing Building on LAWPC Lands" (codes relaxed) scenario, total phosphorus load and in-lake concentration increase to pre-alum treatment levels under the Baseline scenario. It is important to note that even though total phosphorus concentrations are predicted to be similar to the pre-alum treatment levels seen in the late 2010s, the impacts from climate change in 2100 will greatly enhance the probability of blooms compared to similar in-lake concentrations experienced today (see discussion below on filtration waiver violation & bloom frequency). Adjusting for low impact development on new development in the Auburn portion of the watershed (960 new buildings, 256 acres less developed accounting for 30% reduction in development footprint per building, 70% phosphorus export reduction on 835 acres of new developed land) reduces the in-lake total phosphorus concentration by 0.6 ppb. Much of the existing LAWPC lands are located near Lake Auburn. Opening up development on these lands increases the nutrient loading impact (given limited attenuation from direct drainages), and thus, low impact development use on new development has a greater positive impact on water quality than when low impact development was applied to the "Maximum Development Not Allowing Building on LAWPC Lands" scenario. Even with use of low impact development on new development, both maximum development scenarios do not effectively protect the lake from experiencing degraded water quality.

The response parameter of most concern, but that is difficult to model directly, is the probability or risk of cyanobacteria/algae blooms that degrade drinking water quality, impede recreational access, and diminish life-supporting aquatic habitat. For this study, we relied on the scientific literature and historic observed data for Lake Auburn to estimate a relative increase in risk for the following conditions: 1) filtration waiver violation and bloom frequency, and 2) cyanobacteria toxin probability. Generally, this exercise is extremely challenging given the gaps in our understanding of cyanobacteria response to climate change at a global scale and even more so at the local scale. Broad generalizations based on best available studies and observed data were made to assess relative increase in risk for the two conditions.

<u>(1) Filtration waiver violation & bloom frequency</u>: The filtration waiver for Lake Auburn is based on maintaining in-take turbidity concentrations less than 5 NTU and fecal coliform concentrations less than 20 col/100mL. In-take turbidity concentrations are most strongly correlated with in-lake Secchi disk transparency (SDT) readings at the daily scale (Figure 3-3). SDT is a measure of water clarity, which reflects the amount of dissolved or particulate materials in water, namely color, algal cells,

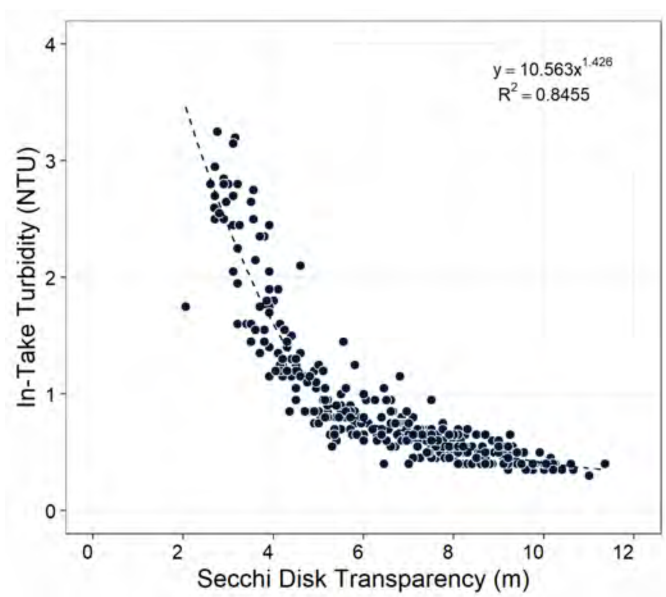

Figure 3-3. In-take turbidity concentrations are strongly correlated with in-lake Secchi disk transparency readings at the daily scale.

Table 3-3. Seasonal weather conditions (precipitation and maximum and minimum air temperature) and average annual water quality conditions (in-lake total phosphorus (TP), in-lake chlorophyll-a (CHLA), and in-take turbidity (TURB)) for each year from 2011-2020. Green highlighted cells indicate years 2011, 2012, and 2018 with blooms. Light blue highlighted cells for precipitation indicate wet years; light orange highlighted cells for precipitation indicate dry years. Dark blue highlighted cells for air temperature indicate cooler-than-normal years (defined as outside one standard deviation of the average); dark orange highlighted cells for air temperature indicate warmer-than-normal years. Generally, wetter-than-normal combined with warmer-than-normal years trigger significant blooms that increase the in-take turbidity concentration.

YEAR	PRECIPITATION (INCHES)					AIR TEMPERATURE (F)								WATER QUALITY ANNUAL AVERAGE		
						WINTER		SPRING		SUMMER		FALL				
	TOTAL	WINTER	SPRING	SUMMER	FALL	TMAX	TMIN	TMAX	TMIN	TMAX	TMIN	TMAX	TMIN	TP (PPB)	CHLA (PPB)	TURB (NTU)
2011	53.87	8.43	17.68	12.71	15.05	33.03	15.51	51.35	34.38	76.97	57.36	59.36	41.97	11.77	10.93	2.80
2012	58.12	11.96	13.02	22.17	10.97	34.35	18.86	56.43	37.20	78.12	58.32	57.09	39.88	14.38	7.32	3.23
2013	44.23	7.69	9.87	13.94	12.73	30.42	15.27	52.09	33.93	76.61	58.45	56.90	38.70	12.03	1.52	2.03
2014	54.17	12.54	13.48	17.99	10.16	31.20	14.70	48.92	29.96	76.92	57.64	56.64	39.81	9.94	2.22	1.10
2015	43.73	10.26	5.81	13.81	13.85	29.20	12.24	52.67	32.98	75.98	58.02	60.37	40.55	9.28	1.72	1.10
2016	45.48	12.27	9.20	10.49	13.52	33.78	16.82	54.01	34.39	79.10	58.24	59.24	41.09	9.13	1.47	1.22
2017	46.09	9.69	13.18	9.61	13.61	31.47	17.12	49.07	31.92	76.00	56.17	59.43	41.04	9.92	1.72	1.52
2018	46.84	8.71	8.30	13.71	16.12	30.93	15.09	51.32	32.85	77.00	56.93	52.35	36.87	10.35	1.30	3.00
2019	51.87	14.01	12.69	12.61	12.56	29.36	13.09	48.67	30.86	77.46	56.10	55.08	36.65	9.68	1.08	0.87
2020	49.29	13.80	10.76	13.99	10.74	33.19	17.74	50.93	32.28	76.47	57.54	57.69	38.88	8.61	1.52	1.00
AVG	49.37	10.94	11.40	14.10	12.93	31.69	15.64	51.55	33.08	77.06	57.48	57.42	39.54	10.51	3.08	1.79
STDEV	4.91	2.28	3.33	3.62	1.91	1.81	2.05	2.43	2.05	0.96	0.85	2.41	1.78	1.74	3.31	0.91
HIGH	54.28	13.22	14.73	17.72	14.84	33.51	17.69	53.98	35.12	78.02	58.32	59.82	41.32	12.25	6.39	2.69
LOW	44.46	8.65	8.07	10.48	11.02	29.88	13.60	49.11	31.03	76.10	56.63	55.01	37.77	8.77	-0.23	0.88

and suspended sediment. Correlations of in-take turbidity or in-lake SDT with other in-lake parameters such as total phosphorus and chlorophyll-a were more variable, indicating that in-take turbidity concentrations are controlled by more than algae or cyanobacteria biomass (e.g., sediment particles).

Severe blooms in Lake Auburn that increased in-take turbidity above 3 NTU occurred in 2011 and 2012 following a series of large storm events during abnormally warm seasonal air temperatures (Figure 3-4, Table 3-3). In 2011, Hurricane Irene produced 3.36 inches of rain over 48 hours in late August and 2.51 inches over 72 hours in early September, which generated significant nutrient-laden runoff to the lake. Hurricane Irene also brought high, sustained winds that likely mixed hypolimnion phosphorus into the upper surface layers. The influx of nutrients along with abnormally warm air temperatures stimulated a bloom in Lake Auburn. In 2012, the severe bloom was triggered by significant nutrient-laden shoreline erosion during several large spring and summer storm events, namely 7.51 inches over one week in early June, 4.76 inches over one week in late June, and 3.38 inches over four days in mid-August. The greater extent and duration of anoxia in 2012, caused in part by an early ice-out, also stimulated internal phosphorus load that fueled the blooms, which ultimately resulted in a fish kill that fall. In 2018, a bloom occurred following several storm events greater than 1-2 inches through the spring, summer, and early fall, which caused sedimentation or nutrient-laden runoff to the lake. SDT readings dropped and in-take turbidity concentrations increased to 3.0 NTU before an emergency algaecide treatment was applied on September 11, 2018.

In all cases, precipitation was the key driver in generating blooms or sedimentation severe enough to rapidly increase in-take turbidity concentrations. Peer reviewed research of Lake Auburn by Messina et al. (2020) showed that lake phosphorus enrichment was most responsive to extreme storm events, when compared to increasing air temperatures, mean precipitation, and windstorms. Blooms were also more severe in 2011 and 2012 when seasonal air temperatures were abnormally warm and average in-lake total phosphorus concentrations were greater than 10 ppb. The trifecta of meeting these three conditions (warm air temperature, total phosphorus greater than 10 ppb, and extreme rain events) in a given

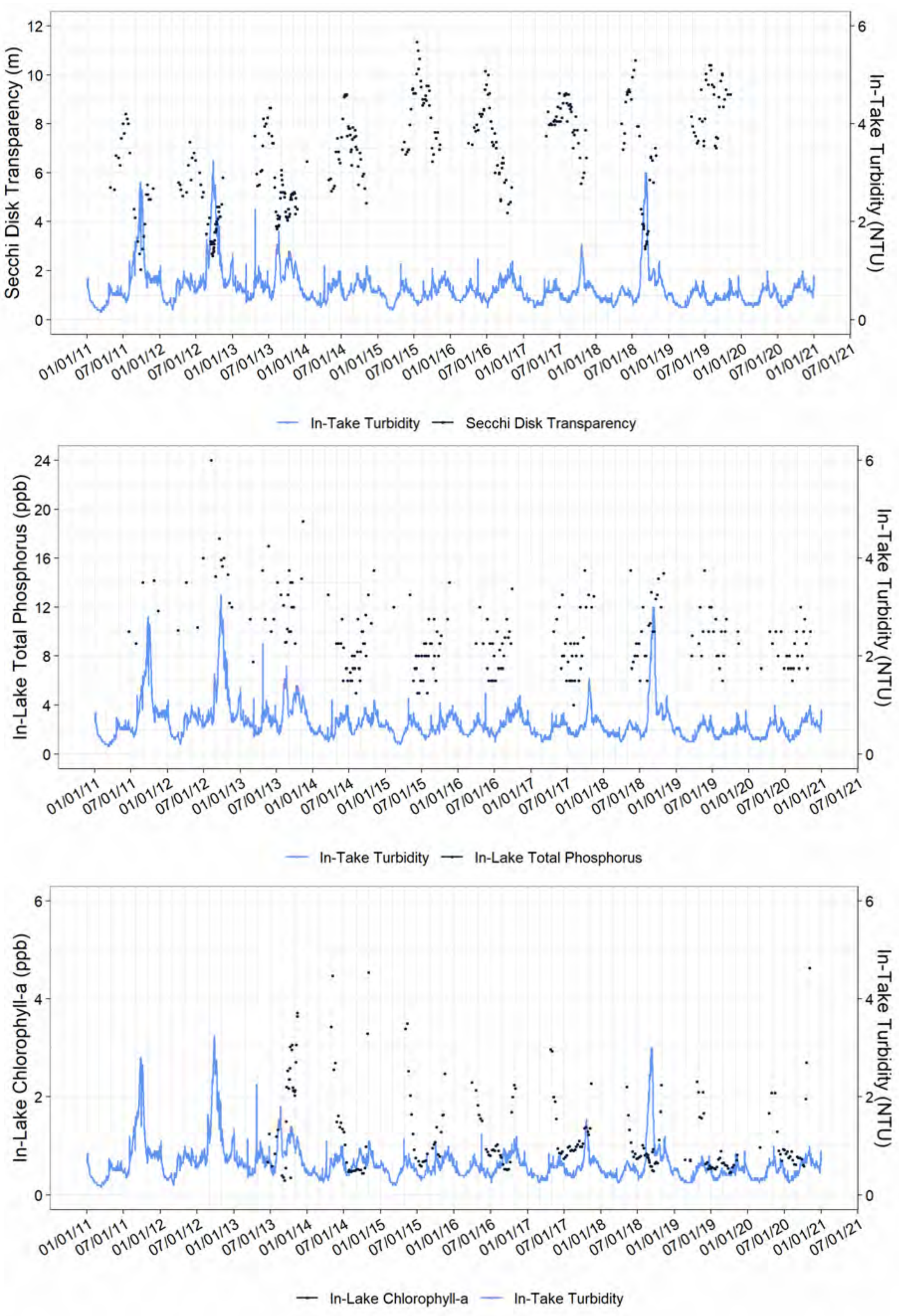

Figure 3-4. 2011-2020 time series of in-take turbidity response compared to key in-lake parameters: Secchi disk transparency (TOP), total phosphorus (MIDDLE), and chlorophyll-a (BOTTOM).

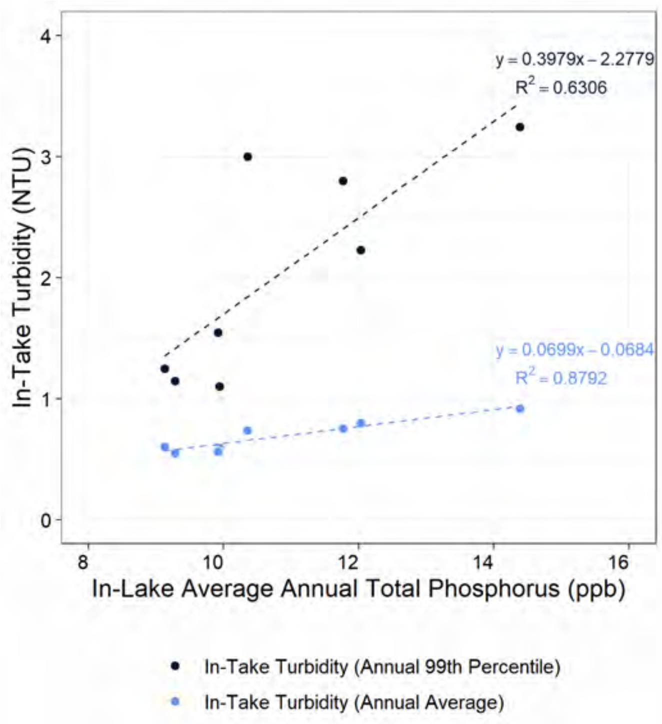

Figure 3-5. In-take turbidity concentration (annual average = light blue; annual 99th percentile = dark blue) correlated to average annual in-lake total phosphorus concentration.

year nearly guarantees a severe bloom that increases in-take turbidity concentrations. CDM Smith (2013) noted that turbidity spikes at the in-take were likely not caused directly by *Gloeotrichia* but rather later blooms of *Dolichiospermum* and *Microcystis*.

Despite historically severe blooms and sedimentation events in the last decade in Lake Auburn, the filtration waiver criteria for in-take turbidity concentrations were never exceeded, only reaching the highest average daily concentration of 3.25 NTU on September 26, 2012. Extrapolating empirical relationships outside the range of observations greatly increases uncertainty in the analysis. Even so, we performed an exercise to estimate the limit of average in-lake total phosphorus concentration at which a filtration waiver violation is likely to occur. We selected the most restrictive criterion for in-take turbidity concentrations of no more than five days exceeding 5 NTU in 10 years. We determined a percentile value of 99.98630137 to apply to daily in-take turbidity concentrations for each year over 10 years to calculate the annual value of in-take turbidity that 0.5 or less days exceed. There was some variability in the linear regression between the 99th percentile of annual in-take turbidity concentration versus the average annual in-lake total phosphorus concentration (Figure 3-5). The standard deviation of the residuals of that linear regression was 0.5, which we subtracted from 5 NTU to account for a margin of safety. We estimated that average annual in-lake total phosphorus concentration would have to reach 17.1 ppb to cause a filtration waiver violation of in-take turbidity concentrations. One notable exception was in 2018 when the average annual in-lake total phosphorus concentration was only 10.4 ppb, but in-take turbidity concentration reached a maximum of 3.0 NTU on 9/12/2018, one day after the emergency algaecide treatment. This suggests that a filtration waiver violation could occur at some average annual in-lake total phosphorus concentration less than 17.1 ppb (but greater than 10 ppb). Note that the 2018 bloom occurred later in the season over a shorter period of time, likely driving the lower average annual phorphorus concentration calculated for that year.

Historic observed data from 2011-2018 (prior to the 2019 alum treatment) for Lake Auburn showed a range of 9.1-14.4 ppb with an average of 10.9 ppb for in-lake total phosphorus concentration, which represents a difference of –1.7 ppb to +3.5 ppb with a standard deviation of 1.8 ppb. We applied this same variability to future condition scenarios and none of the scenarios result in a filtration waiver violation at 17.1 ppb. However, this variability is likely underestimated. Several studies show that interannual variability in nutrient loading and weather is expected to increase over time, and confounding precipitation, air temperature, and phosphorus concentrations could lead to turbidity exceedances at less than 17.1 ppb (Farrell et al., 2020; Kalcic et al, 2019; Messina et al, 2020; Fernandez et al, 2020).

Our estimate is also based on the unlikely assumption that current relationships and underlying conditions of lake dynamics will be the same in the future with climate change and increasing developed land use. The severity of blooms, particularly for potentially toxic cyanobacteria, is projected to increase with increasing temperature due to longer growing seasons and stronger thermal stratification periods that favor cyanobacteria with buoyancy regulation (Ho and Michalak, 2020, Kalcic et al., 2019). Average maximum temperature is projected to increase 7% (4.1 degrees F) and 15% (8.7 degrees F) from 2020-2100 for the RCP 4.5 and 8.5 emission scenarios, respectively. Extreme precipitation events also increase the risk of cyanobacteria blooms by sending short-term pulses of nutrients to the lake or generating short-term water column mixing that promote cyanobacteria recruitment from bottom waters (Cottingham et al., 2021). Extreme precipitation events are expected to increase 40% under both high and low emission scenarios for Maine (Easterling et al., 2017).

Based on our literature review, we generated gross estimates of relative risk for several key factors to consider for drinking water and recreation in Lake Auburn. The partial alum treatment in 2019 reduced the risk of blooms and the immediate need for a filtration plant. The future “Business As Usual” (no code changes) scenario and the future "Maximum Development Not Allowing Building on LAWPC Lands" (codes relaxed) scenario would likely increase the bloom risk to a level similar to the risk prior to the alum treatment. A filtration waiver violation would be unlikely or low risk, but taste and odor complaints may drive the need for a filtration plant. The future "Maximum Development Allowing Building on LAWPC Lands" (codes relaxed) scenario would greatly increase the risk of blooms (to nearly every year) with a higher risk for a filtration waiver violation that would necessitate the construction of a filtration plant. These blooms would occur even with regular alum treatments already instated as an in-lake management technique; additional bloom controls would be costly.

> In summary, none of these future scenarios meet an acceptable water quality goal that maintains high quality water for drinking water, recreational use, and aquatic health for Lake Auburn.

The use of low impact development strategies on all new development in the Auburn portion of the watershed would not significantly reduce the risk of blooms for the "Business As Usual" and "Maximum Development Not Allowing Building on LAWPC Lands" scenarios. The risk of blooms remains at 40%, a filtration waiver violation remains unlikely or low risk, and taste and odor complaints remain likely (and may drive the need for a filtration plant). The use of low impact development strategies on all new development in the Auburn portion of the watershed would, however, significantly reduce the risk of blooms for the "Maximum Development Allowing Building on LAWPC Lands" scenario. The risk of blooms reduces from 80% to 50%, a filtration waiver violation improves from a medium risk to a low risk, and taste and odor complaints improve from many to likely (and reduce the possible need for a filtration plant).

In summary, none of these future scenarios which consider Auburn-only changes to regulatory and management approaches meet an acceptable water quality goal that maintains high quality water for drinking water, recreational use, and aquatic health for Lake Auburn. The AWD and the City of Auburn will need to be constant stewards of the watershed, begin working with the headwater towns on instituting protection efforts watershed-wide, and minimize increases in nutrient load to the lake to best protect water quality for both drinking water and recreation. It is important to understand that a filtration plant does not allow for greater development of the watershed because the filtration plant only treats extracted drinking water for the consumer and does not treat in-lake water quality for recreation and for meeting State criteria for designated uses.

(2) Cyanobacteria toxin probability: One significant yet unknown threat to Lake Auburn's future water quality is toxins from cyanobacteria blooms. Lake Auburn has some of the highest counts of *Gloeotrichia enichulate*, a potentially toxic cyanobacterium, among studied northeastern lakes (Carey et al., 2012). Studies have shown that warmer air and water temperatures increase the amount of cyanobacteria in the water column, and toxins are more likely to be released (McQueen and Lean 1987, Walls et al., 2018). Walls et al. (2018) found that warming more than 20 °C, especially between 20 °C and 25 °C, increases toxic microcystin release by 36%. Other studies modeling future conditions suggest that longer summers may increase cyanobacterial abundance but decrease the risk of harmful toxin concentrations (Ho and Michalak, 2020). These findings suggest that there may be an optimal temperature range and growing season length in the future that will support toxic cyanobacteria blooms in Lake Auburn. It is probable that a filtration plant will need to be considered to remove toxins and taste and odor-causing compounds from cyanobacteria to protect public health; however, filtration plants with the capacity to remove organic contaminants are costly. If a filtration plant is needed for organic contaminants, then it is likely that Lake Auburn is at that point unsuitable for recreation for significant portion of the year.

Residents living in proximity to Lake Auburn should also be aware of other health threats associated with toxic cyanobacteria blooms. Dr. Jim Haney at the University of New Hampshire is at the forefront of aerosolized cyanobacteria research. His and others' research shows that people living within 0.5 miles of a waterbody affected by frequent toxic cyanobacteria blooms are at significantly greater risk for amyotrophic lateral sclerosis (ALS), a progressive neurodegenerative disease that affects nerve cells in the brain and spinal cord (Caller et al., 2009; Caller et al., 2012; Caller et al., 2013; Stommel et al., 2013; Torbick et al., 2014; Torbikc et al., 2018).

Recreational Opportunities

Swimming

Swimming is currently not allowed anywhere in Lake Auburn, and as discussed in Section 2, there has been a ban on "bathing" since the late 1800s. The swimming prohibition is intended to preserve many desirable benefits, most prominently protecting drinking water quality and

Table 3-4. Baseline and scenario model results for total phosphorus (TP) load (kg/yr) and in-lake TP concentration (ppb), along with gross estimates for water quality risks related to drinking water and recreation in Lake Auburn.

SCENARIO	YEAR	TP LOAD (KG/YR)	TP (PPB) - AVG	TP (PPB) - MIN	TP (PPB) - MAX	Bloom Risk	Taste/Odor	Filtration Waiver Violation Risk	Filtration Plant Needed?
Baseline or "Existing Conditions"	2018	1,114	10.9	9.2	14.4	40%	Complaints	None	No, borderline for taste/odor
Baseline + Alum Treatment	2020	842	8.3	6.6	11.8	10%	Likely Few Complaints	Likely None	No
Baseline + Alum Treatment + Climate Change (RCP 4.5)	2100	831	8.2	6.5	11.7	NA	NA	NA	NA
Baseline + Alum Treatment + Climate Change (RCP 8.5)	2100	803	8.2	6.5	11.7	NA	NA	NA	NA
Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "Business As Usual" Buildout (No Code Changes)	2100	957	9.5	7.8	13.0	40%	Complaints Likely	Low Risk	Likely no, but borderline for taste/odor
Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "Maximum Development Not Allowing Building on LAWPC Lands" Buildout (Codes Relaxed, LAWPC Lands Remain Protected)	2100	994	9.9	8.2	13.4	40%	Complaints Likely	Low Risk	Possibly yes due to taste/odor
Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "Maximum Development Allowing Building on LAWPC Lands" Buildout (Codes Relaxed, LAWPC Lands Open for Development)	2100	1,077	10.7	9.0	14.2	80%	Many Complaints	Medium Risk	Likely yes due to taste/odor and higher risk for toxic cyanobacteria
Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "Business As Usual" Buildout (No Code Changes) + Low Impact Development Standards	2100	943	9.4	7.7	12.9	40%	Complaints Likely	Low Risk	Likely no, but borderline for taste/odor
Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "Maximum Development Not Allowing Building on LAWPC Lands" Buildout (Codes Relaxed, LAWPC Lands Remain Protected) + Low Impact Development Standards	2100	959	9.5	7.8	13.0	40%	Complaints Likely	Low Risk	Likely no, but borderline for taste/odor
Baseline + Alum Treatment + Climate Change (RCP 4.5) + Future "Maximum Development Allowing Building on LAWPC Lands" Buildout (Codes Relaxed, LAWPC Lands Open for Development) + Low Impact Development Standards	2100	1,015	10.1	8.4	13.6	50%	Many Complaints	Low Risk	Possibly yes due to taste/odor
Lake Auburn Water Quality Goal Recommendation	2100	900	9.0	7.6	11.9	10-20%	Few Complaints	Low	No

maintaining the filtration waiver. Swimming was once allowed at Lake Auburn's outlet park at the lake outlet (downstream of Route 4), but the "Outlet Beach" swimming area has been closed since 2012 due to elevated fecal indicator bacteria counts. Approximately 33% of the routine summer fecal indicator bacteria monitoring samples collected at Outlet Beach between 2005-2012 were elevated. It was determined that the source of the fecal indicator bacteria was not the recreational activities themselves (swimming, fishing, picnicking), but rather 1) lake characteristics at the location of the swimming beach where there was poor water circulation, 2) the lack of stormwater control practices in place to prevent runoff into the lake from significant areas of impervious surfaces around Route 4, and 3) waterfowl congregation in the park vicinity (CEI, Inc., 2013). The City has continued to study the possibility of reopening Outlet Beach (Lewiston Sun Journal, 2020), but informal proposals have also considered the northern shores of the lake along Lake Shore Drive, where poor circulation would likely not be an issue.

To assess the hypothetical regulatory impact of a swimming area, the project team contacted the Maine Drinking Water Program for information on how such a decision would affect the filtration waiver, as well as any other regulatory considerations at the State level. Drinking Water Program staff indicated that a swimming area in Lake Auburn would likely violate the filtration waiver, which, along with a City ordinance, requires "no swimming or body contact" with the water (Maine Drinking Water Program, pers. comm.). The State of Maine and EPA would need to work with the AWD and City of Lewiston to review any proposed swimming area location and its impacts to determine whether the filtration waiver could be maintained. Given its high probability of causing a filtration waiver violation, a swimming area will likely not be feasible for Lake Auburn at any time unless State and federal authorities sign off.

Nevertheless, as an exercise for this study, the environmental impacts of a hypothetical swimming area were sketched out in preliminary fashion, along with appropriate measures for avoidance and minimization of impacts to the lake and the drinking water source. If a swimming area were to be re-instituted at Lake Auburn, the concern would not be about additional phosphorus loading but about fecal indicator bacteria loading and turbidity increases. Many actions would need to take place to ensure that the area was not contributing to water quality degradation, including (but not limited to) the following:

- The swimming area would need to be in a different part of the lake, not at the outlet where there is poor circulation with proximal impervious surfaces. It is possible that a candidate location for a swimming area does not currently exist, especially given that it would be restricted to the northern half of the lake (across from the in-take) away from any milfoil areas (e.g., the Basin) and major tributary inflows (e.g., the Basin, Townsend Brook).
- The swimming area should be roped off with buoys, and swimming outside the buoyed area should be prohibited, including private shorefront properties.
- The access area would need to have adequate facilities to prevent human and pet waste from entering the lake, such as installing maintained bathrooms and pet waste disposal bins, or better yet, an enforced ban on pets.
- The access area would need to have adequate shoreline buffers and stormwater control practices in place to reduce runoff into the lake. Studies show that stormwater control practices will be less effective and more necessary for managing lake water quality with climate change, so it is not recommended to introduce a swimming area to the lake unless an indefinite commitment to implementing and maintaining all stormwater control practices is made to ensure minimal nutrient loading occurs at the location (Bosch et al., 2014).
- The number of visitors per day would need to be capped to prevent overcrowding. A suitable limit would be no more than 50 people at any given time. The City could offer paid stickers to Auburn residents to help offset some of the cost to maintain and limit the number of visitors.
- The access area would need to be designed so as to not attract waterfowl that contribute to high fecal indicator bacteria counts (i.e., no large grass lawns). Studies recommend that regular cleanings and gull and geese deterrent strategies are critical for reducing onshore inputs of fecal indicator bacteria (Kinzelman et al., 2003 and 2004; Converse et al., 2012).
- A City staff person and daily attendant would need to be responsible for operating and maintaining the swimming area, enforcing rules, and coordinating with LAWPC.
- Additional water quality testing would need to be performed in and around the swimming area to assess impacts to the lake.
- A swimming area should only be allowed on a trial basis and continued only after regular inspections and water quality testing confirm that the swimming area does not pose a threat to lake water quality.

Implementing these common sense measures to avoid and minimize risk would require a considerable level of effort on the part of the City of Auburn in coordination with LAWPC. When considering the environmental risk, however well-managed it may be, managers must acknowledge the uncertainty surrounding the lake's ability to absorb new impacts without degrading water quality, especially the interaction between the different types of impacts such as phosphorus loading, climate change, and shifting development patterns. If a tipping point is reached, the cost to maintain a swimming area may outweigh the recreational benefits in a manner that is hard to capture in the economic analysis in Section 4. Further, at some point in the future, a swimming area may not be feasible given the increasing likelihood of toxic cyanobacteria bloom occurrence, which would preclude safe bodily contact during periods of toxicity.

Boating & Fishing

Boating is allowed on Lake Auburn, primarily for fishing during the ice-off season, given that no bodily contact recreation associated with boating (e.g., tubing, water-skiing, wakeboarding) is permitted. Whether from a boat or the shoreline, many local recreators enjoy Lake Auburn for its fishing. Historically, Townsend Brook had major smelt runs in the spring that fed the lake. Up until 2012, lake trout (a.k.a., togue) were the prominent fish species being caught in the lake, but a massive lake trout fish kill in the fall of 2012 changed the trophic structure of the lake so that landlocked salmon replaced the lake trout as the dominant recreational fishery species (Portland Press Herald, 2013). The trophic structure of the lake may continue to change as water quality is threatened by increased development and climate change. Losing species anywhere on the trophic chain, whether top predator fish species or zooplankton, can upset the balance and cause a trophic cascade whereby one species thrives at the expense of another. Upsetting the delicate balance of lake ecosystems can have important implications for water quality and can trigger or exacerbate water quality degradation.

For the physical activity of boating, the two major water quality concerns are 1) introduction and/or spread of invasive species and 2) shoreline erosion through wave action.

<u>Invasive Species Introduction or Spread</u>: Lake Auburn is already subject to invasive species pressure from variable leaf milfoil (*Myriophyllum heterophyllum*) growing in the Basin and near the Basin inlet on the north end of the lake. There is ever-present risk that boat traffic could introduce and spread other invasives such as curly-leaf pondweed (*Potamogeton crispus*), hydrilla (*Hydrilla spp.*), and brittle waternymph (*Najas minor*). Milfoil management efforts have been conducted in the Basin and Lake Auburn since the early 2000s. Benthic mats have been installed to reduce milfoil populations in the Basin, but there is concern about the best management strategy in Lake Auburn because sediment disturbance can cause release of phosphorus and increase total organic carbon. While variable-leaf milfoil takes up and removes phosphorus from the water during the growing season, it also takes up significant phosphorus from the sediment, all of which is released back to the water following death and decay of the plant (Chagnon and Baker, 1979).

All of the aforementioned invasive aquatic plants can be easily transported accidentally into Maine lakes via boats, boat trailers, vehicles, or equipment. Although carrying invasives on a boat is illegal, many boaters do not know when they are transporting invasive species from one lake to another. Research shows that more than two-thirds of boaters do not inspect or clean their own boats, so a mandatory boat inspection is critical to prevent future infestations (Rothlisberger et al., 2010). Courtesy boat inspector programs have been implemented throughout the State, including Lake Auburn, to check boats prior to entering Maine lakes; however, these programs are staffed by volunteers who are not always available to check all boats. Invasive plants are problematic because they grow rapidly and outcompete native aquatic vegetation. Many invasive plants can reduce levels of oxygen in the water, which threatens water quality and can contribute to fish kills. Furthermore, researchers have shown that invasive plant species infestations can reduce property values by as much as 16% (Zhang and Boyle, 2010).

Photo Credit: Bangor Daily News

Maine DEP has developed a model called Lake Vulnerability to Invasive Aquatic Plants that uses volume of use, proximity to infested waterbody, and potential for colonization to determine the vulnerability of Maine lakes to invasive spread (Maine DEP, 2019). Under current boating conditions, Lake Auburn is already considered high risk and scores a 5/5 for risk of boats introducing invasives to the lake. Given the results of this model, it is reasonable to assume that more boat traffic will further increase the likelihood of invasive plant spreading in Lake Auburn. Thus, the best path forward for Lake Auburn is continuing to implement strict invasive management practices under the current recreation restrictions, such as ensuring full staffing of boat inspection stations.

Shoreline Erosion: Currently only small watercraft are allowed on Lake Auburn. Larger watercraft for enhanced recreational opportunities such as water sports (tubing, skiing, wakeboarding) would increase the risk of shoreline erosion from boat wake induced wave action. CEI, Inc. (2010) noted several locations around the lake, including along Lake Shore Drive, that showed evidence of shoreline erosion, though largely associated with vehicle and pedestrian access to the lake in the form of networks of informal "social trails." Erosion of sediments along the shoreline brings in phosphorus to the lake which can increase the total nutrient availability for cyanobacteria and other phytoplankton. Allowance of only small watercraft restricted to areas away from the in-take should continue, and improved stabilization techniques at vehicle and pedestrian access points along the lake shoreline should be implemented, along with clear and effective barriers to foot and vehicle access.

Trail-Based Recreational Activities

A trail network currently exists on LAWPC lands, most prominently the Whitman Spring Road trail that extends north-south along the western side of Lake Auburn. Motorized vehicles are not allowed on the trails, which can greatly help reduce compaction and erosion of trails. Leashed dogs and horses are allowed along with biking with fat tires. LAWPC maintains pet waste bag stations at both ends of the Whitman Spring Road trail. A Southern Link trail has been proposed that would connect from Route 4 on the east side of Lake Auburn across the southern portion of the watershed to the southern end of the Whitman Spring Road trail. A recommendation of this study is that LAWPC coordinate with local youth conservation groups or AmeriCorps to perform annual maintenance of the trails and install best practices that limit erosion of the trails, especially those sections nearest the lake. In addition, surveying how much horse manure may be found on the trails to inform a reconsideration of horseback riding near the lake is recommended, as manure can be a significant nutrient source in sufficient quantities. Finally, it is recommended that the City acquire permanent recreational trail easements to LAWPC properties with trails for guaranteed public access in the future.

Snowmobiling

About 1.4 miles of snowmobile trails on LAWPC lands connect with nearly seven additional miles of trails within the watershed. The trails are not only used for snowmobiling but also for cross country skiing and snowshoeing. The Perkins Ridge Snowmobile Club obtains a trail maintenance permit each winter season and grooms Whitman Spring Road and a few connecting trail segments on LAWPC lands. Snowmobiling and related winter activities on trails are considered to have minimal impact on water quality, as the risk of erosion is very low during periods of snow cover combined with frozen ground.

Hunting

LAWPC allows hunting and trapping on 1,273 acres of LAWPC lands (not including lands on which LAWPC holds a conservation easement). Hunters review LAWPC rules and sign a land use courtesy card indicating which parcels can be hunted. LAWPC permits hunting with firearms on 1,053 of these acres, while bow hunting is allowed on an additional 220 acres. Hunting is considered to have minimal impact on water quality as it does not concentrate traffic close to the lakeshore or funnel enough traffic to impact vegetation or cause bare soil and erosion.

Forest Management

Intact forests are critical for lake water quality, as forests prevent soil erosion, mitigate flooding, and reduce the amount of sediment and nutrients that are delivered to lakes. Studies specific to Maine show that natural infrastructure such as forests and wetlands are among the cheapest and most effective ways to maintain water quality and filtration waivers (World Resource Institute, 2013). A cost-effectiveness analysis for Sebago Lake found that the cost of reforesting the watershed, installing riparian buffers, securing conservation easements, upgrading culverts, and certifying forestry practices as sustainable was $12 million to $111 million less than installing a membrane filtration system (Daigneault & Strong, 2018).

Forest management, namely timber harvesting and replanting, has been a focal point of the AWD's watershed protection strategy for Lake Auburn since the 1930s. The AWD enlisted the Maine Forest Service for forest management assistance in the 1960s and has been contracting with a licensed forester for forest management since the 1980s. Currently, the AWD's forester Chip Love prepares the harvest plans for LAWPC lands. The harvest plans are reviewed by the State Forester out of the Gray office. Mr. Love also prepares plans for private landowners on occasion and sends those to the State Forester for review. For harvest plans on private lands in the Lake Auburn watershed prepared by foresters other than Mr. Love, LAWPC uses Mr. Love for plan review.

These individual harvest plans follow LAWPC's forest management plan (Love, 2013) and adhere to harvesting standards set forth in City ordinances. Auburn's Shoreland Overlay District Ordinance contains "Timber Harvesting Standards" applicable to the 250-foot shoreland zone of Lake Auburn, which follow Maine's statewide standards for timber harvesting and related activities in shoreland areas detailed in Chapter 21 of the Department of Agriculture, Conservation and Forestry rules and regulations (2015). These statewide standards serve multiple purposes: to prevent and control water pollution, including sediment and excessive nutrient inputs; to protect wildlife habitat; and to ensure sustainable timber harvesting that does not harm forest health. Notably, the purpose of protecting drinking water supply is not listed. Guidelines for forest management are also set at the State level through the Maine Forest Service's manual, "*Best Management Practices for Forestry: Protecting Maine's Water Quality*" (Maine Forest Service, 2017).

The "Timber Harvesting Standards" in Auburn's Shoreland Overlay District Ordinance are summarized below:

1. No substantial accumulation of slash shall be left within 50 feet of the lake or its streams. Between 50-250 feet of the lake or its streams, all slash shall be disposed of in such a manner that it lies on the ground and no part thereof extends more than 4 feet above ground.

2. Skid trails, log yards, and other sites where the operation of logging machinery results in the exposure of substantial areas of mineral soil shall be located such that an unscarified filter strip is retained between the exposed mineral soil and the lake or its streams. The width of the strip shall vary according to the average slope of the land. For instance, a 75-foot buffer is needed for slopes 10% or less while a 136-155-foot buffer is needed for slopes between 40-50%. The strip widths presented in the City ordinance are more restrictive than those set in the Chapter 21 State rules and regulations.

3. Harvesting operations shall be conducted in such a manner and at such a time that minimal soil disturbance results. Adequate provision shall be made to prevent soil erosion and sedimentation of surface waters. Chapter 21 State rules and regulations state that timber harvesting be conducted when surface waters are frozen and snow covered, when the activity will not result in any ground disturbance. Winter harvesting was mentioned as being conducted in the 2013 LAWPC Timber Cruise Report and Forest Management Plan.

4. Harvesting operations shall be conducted in such a manner that a well-distributed stand of trees and other vegetation is retained.

5. Harvesting activities shall not create single openings greater than 7,500 square feet in the forest canopy.

6. In any stand, harvesting shall remove not more than 40% of the volume of trees in any 10-year period. A stand means a contiguous group of trees, sufficiently uniform in species, arrangement of age classes, and conditions, to be identifiable as a homogenous and distinguishable unit. This represents selection of Option 1 in the Chapter 21 State rules and regulations.

7. Within 100 feet horizontal distance of the lake and within 75 feet horizontal distance of streams or major wetlands, there shall be no clear-cut openings and a well-distributed stand of trees and other vegetation, including existing groundcover, shall be maintained.

More specific guidance for forest management in the Lake Auburn watershed is sparse. There is no mention of forest management in the LAWPC by-laws. Timber management or harvesting operations are exempt from the Phosphorus Control Ordinance, as long as the operations are "conducted according to a management plan prepared and supervised by a registered forester or the AWD." As stated in Section 2 under the Farm and Forest Management section, we recommend that timber harvesting in the Lake Auburn watershed be conducted not only in accordance with a harvest plan prepared and supervised by a registered forester but also in accordance with a comprehensive erosion and sedimentation control plan specified under the Phosphorus Control Ordinance.

In addition, the Lake Auburn Watershed Overlay District Ordinance specifies that:

> *"Harvesting of trees shall be permitted only after a plan prepared by a qualified forester is submitted to and approved by the Water District. Such plan will be approved or disapproved on the basis of its conformance with good watershed management practices for domestic water supplies."*

City ordinances reference "Timber Harvesting Standards" (summarized above) from Chapter 21 State rules and regulations that help protect water quality but not necessarily specifically for water supply protection. Therefore, no clear guidance or standard is provided to evaluate whether or not plans conform with "good watershed management practices for domestic water supplies."

The 2013 LAWPC Timber Cruise Report and Forest Management Plan for the Lake Auburn watershed specifies:

> *"The primary objective is to manage the property to protect the watershed for Lake Auburn. Uneven aged management maintaining a healthy, vigorous forest focusing on growing and regenerating softwood species will best accomplish this goal. Hardwood leaves can cause problems for a water supply. These goals are compatible with good forest management and a continued conservative approach will add to this effort. Other objectives include: improved forest growth and productivity, aesthetics, improved wildlife habitat, maintaining open space, and limited recreational potential. All of these goals are attainable with little or no detriment to each other. In some cases, wood production and income may be lost due to conservative management of the forest. Due to the value of the water supply this will be of little or no consequence."*

Much of the 2013 LAWPC Timber Cruise Report and Forest Management Plan focuses on the income generation from the stands and minimally on water resources protection, such that the forest management plan would not be considered meeting its primary objective of being written for watershed protection for a water supply. In addition, individual stand harvest plans provide minimal information on the natural resources present other than the composition, quality, and income potential of trees. No references or greater discussion are provided for justifying the preference for softwood over hardwood species. Instead, individual stand descriptions in the forest management plan mention management treatments that focus on growing "high value trees such as white pine and red oak" and using selective harvesting to remove "weaker low quality trees" for the establishment of more "desirable species." To the contrary, some studies indicate that mixed wood stands have greater benefits for sustainability of wildlife habitat and water quality protection in the face of climate change (Kabrick et al., 2017). It is also unclear whether the implementation of the "Timber Harvesting Standards" on LAWPC lands has achieved the previously stated objectives. No long-term studies have been conducted on the biodiversity of habitats and wildlife species or changes in surface runoff before and after harvests to evaluate the effectiveness of implemented forest management in the Lake Auburn watershed. The soils identified in the forest management plan are soils prone to severe erosion, but there is no mention of how soils are integrated into management decisions at the stand level other than for their suitability for tree growth.

While the "Timber Harvesting Standards" used on LAWPC lands are technically sound and follow industry standards for proper timber harvesting, there remains a certain level of risk with employing harvesting within the Lake Auburn watershed, especially on those LAWPC lands bordering the lake. The goal of drinking water protection should take precedence over timber harvesting in these sensitive areas. Even with proper forest management, timber harvesting can still increase runoff volume after a storm, particularly within the first year, which can increase the delivery of total phosphorus and dissolved organic carbon to a lake (Reinhart et al., 1963; Winkler et al., 2009). Removing trees decreases canopy interception and evapotranspiration and thus temporarily increases water yield (and possibly sediment and nutrient load) from the land (Fulton & West, 2002). The potential for sediment delivery to streams is a long-term concern for nearly all harvesting activities and roads or skid trails regardless of their use or age (EPA, 2020). There is also the risk of fuel or hydraulic fluid contamination from machinery leaks. In summary, timber harvesting is not a strategy for water supply protection that reduces contamination

Photo Credit: LAWPC

risk, but rather constitutes an additional and perhaps unnecessary risk to the water supply.

For comparison, the Kennebec Water District (KWD) has a forest management plan for its 344 acres of protected shorefront lands. The plan's primary goal is to "grow and harvest commercial forest products to establish and perpetuate an uneven aged, mixed species forest to protect the water quality in China Lake." The plan states that harvesting every 15-20 years (up to 30 years) follows established statewide BMPs. The plan features discussion and harvesting recommendations that accommodate and enhance wildlife habitats. The China Lake west basin watershed is of comparable size to that of Lake Auburn, as is the land area directly under KWD control.

As an additional point of comparison, the Portland Water District (PWD) focuses largely on conserving large tracts of private land in the Sebago Lake watershed and received a substantial grant in 2020 to develop forest management plans for implementation of harvesting practices that minimize impacts to water quality. The Sebago Lake watershed is much larger than the Lake Auburn watershed and incorporates a much larger acreage of private forestry, necessitating the focus on private land, but the direct water quality focus is clear. In both the KWD and PWD examples, the stated goal of the forest management plans is to reduce the impact of harvesting activities on water quality and not for the improvement or protection of the water supply.

Based on our review of forest management in the Lake Auburn watershed, we provide the following recommendations (in conjunction with improved general land management strategies, see Land Purchase Strategy):

- Develop a comprehensive natural resource management plan rather than a standard forest management plan for LAWPC lands that focuses firstly on drinking water protection and secondly on wildlife habitat protection if in the interest of public water supply protection, with multiple management options offered. Harvesting of timber can be identified as a tool for managing the mix of species on the landscape but not for protecting water supply; any income generated by such timber harvesting is minimal and should be viewed as incidental and not as a driver for watershed management. Include a comprehensive literature review of best practices when it comes to natural resource management strategies in water supply watersheds. The review should help to justify or alter current strategies.
- Develop natural resource inventories for all LAWPC lands to map critical streams (perennial and intermittent), wetlands, vernal pools, cover types, rare, threatened, and endangered species present, etc. Develop individual natural resource management plans for each LAWPC parcel and set clear management objectives and methods to achieve water resource and wildlife habitat protection.

If timber harvesting continues in the Lake Auburn watershed on LAWPC or private lands, then we recommend the following:

- Have the Shoreland Overlay District Ordinance specifically reference Chapter 21 of the Department of Agriculture, Conservation and Forestry rules and regulations for the "Timber Harvesting Standards" since the State standards are more detailed and explicit compared to the City ordinance summary.
- Consider extending the Shoreland Overlay District Ordinance "Timber Harvesting Standards" to the entire Lake Auburn Watershed Overlay District Ordinance to apply standards beyond the 250-foot shoreland zone.
- Conduct harvesting not only in accordance with a management plan prepared and supervised by a registered forester but also in accordance with a comprehensive erosion and sedimentation control plan specified under the Phosphorus Control Ordinance.
- Best management practices that limit the negative impacts from timber harvesting, such as erosion and sedimentation controls and construction of access roads, should be clearly described and expanded upon over what is available in the City ordinances. Require more stringent BMPs during harvesting, such as the following:
    - » Continue to maintain a 75-foot buffer from mapped perennial streams, but consider expanding the 75-foot buffer standard to intermittent streams with recognition of ephemeral streams. Consider applying a no skidder ban up to 150 ft from perennial and intermittent streams and wetlands and up to 175 ft from major waterbodies and zoning these areas as protected Riparian Buffers (Trout Unlimited, 2014).
    - » Use portable, temporary bridges for all skidder stream crossings, as the use of bridges will significantly reduce sedimentation and protect the surrounding ecosystem (Wilkerson & Gunn, 2012; Croke & Hairsine, 2006).
    - » Consider extending the minimal harvest rotation to more than 10 years (20-30 years is the recommended minimum).
    - » Require harvesting techniques that minimize ground disturbance (which is shown to be the primary driver of increased sedimentation following harvesting, see Mohammad et al.,

2020), such as suspending logs for transport as opposed to dragging logs, avoiding heavy machinery wherever possible, and mulching.

- Monitor and enforce proper BMP installation and include a written and photographed assessment of BMPs utilized and the identification and correction of any BMP failures. Require pre and post monitoring on managed woodlots to determine the efficacy of BMPs. Monitoring should include water quality testing of Lake Auburn tributary streams, habitat evaluation, and wildlife species identification.

Land Purchase Strategy

Over the nearly three decades of its existence, LAWPC has successfully acquired a significant amount of land for drinking water protection in the Auburn portion of the Lake Auburn watershed. Beginning with 720 acres at its outset in 1993 (consisting of lands that were under the control of AWD or the City of Lewiston), LAWPC now controls 1,975 acres (21% of the entire watershed), with 1,320 acres (14% of the entire watershed) in direct LAWPC or AWD/LWD ownership and the remaining as conservation easements (which are often monitored by the Androscoggin Land Trust) or Life Estates (where landowners give control of their land to LAWPC). Most importantly for water quality, LAWPC controls lands comprising 80% of the total length of the shoreline of Lake Auburn. As defined by their by-laws, LAWPC's primary land management objective is to manage their properties for the protection of Lake Auburn as a drinking water source, with secondary objectives being improved forest growth and productivity, aesthetics, improved wildlife habitat, maintaining open space, and recreational potential. These objectives all fall under the broad umbrella of conservation and do not inherently conflict.

This study reviewed the pattern of land control and acquisition by LAWPC and evaluated whether the current status quo is sufficient for protecting drinking water quality, based on the findings of the modeling component of this study. The project team also communicated with stakeholders about future priorities for land purchase.

The water quality modeling analysis undertaken by this study showed that removing building restrictions from LAWPC-owned protected parcels in the watershed (i.e., selling the LAWPC parcels for residential development) would allow for an additional 368 new homes to be built, resulting in an additional 83 kg/yr of total phosphorus load to Lake Auburn. The additional nutrient load would increase average annual in-lake total phosphorus concentration by 0.8 ppb and increase the annual bloom probability from 40% to 80%, forcing the necessity of a filtration plant. Given these results, it is reasonable to conclude that LAWPC land protection initiatives have been highly successful at protecting lake water quality.

Sid Hazelton, AWD Superintendent, communicated to the project team that in the past, land purchase prioritization had been dictated by the water supply protection "zones" defined in LAWPC by-laws and that Zone 1 properties were highest priority, followed by Zone 2, and so on (S. Hazelton, pers. comm.). (The LAWPC water supply protection zones, not to be confused with municipal land use zoning ordinance, are described in detail in Section 2.) Superintendent Hazelton, who also serves as a clerk for LAWPC, also articulated his view that nearly all the properties along the shoreline or within the watershed that could be considered critical to lake water quality protection have already been acquired and protected by LAWPC. He also commented that both AWD and LAWPC are sensitive to the concern that water supply conservation lands take properties off the tax rolls and that excessive property acquisition by LAWPC would put undue cost onto the taxpayers of Auburn. Instead of proposing more land acquisition, Mr. Hazelton described the importance of working with the City of Auburn and the upper watershed municipalities to control stormwater runoff from new development, to improve stormwater management on old development by retrofitting with best management practices, utilizing the help of the Maine DEP (in the form of Clean Water Act Section 319 Watershed Assistance grant funds), and to continue to monitor water quality for early warnings of any undesirable shifts in water quality status in the lake or its tributaries.

Given the finding of this study's modeling effort that the LAWPC-protected lands have been effective at preserving Lake Auburn water quality, as well as the opinion expressed by Superintendent Hazelton to work with partners rather than acquire new LAWPC lands, we recommend a collaborative way forward that strengthens and makes permanent the existing protections while pulling in more allies for conserving lands in the upper watershed. As discussed in relation to forest management, there is room for improvement in aligning water supply protection with other management objectives for protected or conserved lands. Specifically, we recommend that all properties owned and/or managed by LAWPC have a natural resource inventory completed, with natural resources, management actions and objectives, and current uses clearly identified for each. We recommend that LAWPC work with local conservation groups and land trusts to purchase land in the watershed outside of Auburn. Finally, we also recommend that LAWPC consider putting all their properties into permanent conservation. These properties are currently protected under the LAWPC by-laws but provide no higher-level legal protection from future development if said by-laws were to be revoked.

4 Analysis of Economic Impacts

This section provides an analysis of economic benefits and costs for various development and water quality scenarios for the Lake Auburn watershed. The analysis is intended to quantify the potential monetary impacts of various scenarios, which can be used to broadly inform city and water system managers on future watershed planning. The analysis utilizes well-established economic methods, land use, and water quality information to systematically evaluate these scenarios.

Photo Credit: Sun Journal

Benefit-Cost Analysis

The economic impact assessment followed a seven-step process for conducting a benefit-cost analysis (BCA), illustrated in Figure 4-1 (Buncle et al., 2013; Greenhalgh et al., 2017; Robinson et al., 2019). A total of four scenarios were evaluated, including existing conditions in the Lake Auburn watershed. Each scenario included a specific set of benefits and costs. The primary benefits were: (1) City of Auburn property taxes collected and (2) recreational opportunities. The key economic costs of varying development in the watershed were: (1) costs of water treatment, filtration, and purification (e.g., alum treatments, water treatment (without plant), filtration plant construction, operation, and maintenance), (2) filtration plant interest (debt servicing) costs, (3) expansion of City services and social equity costs, and (4) watershed protection and restoration costs (including regulatory compliance costs).

All benefits and costs accounted for in our study were monetized on an annual basis and aggregated over time, assuming an 80-year timeframe and a discount rate of 3%. The 80-year timeframe (to 2100) aligned with the water quality modeling scenarios. The discount rate was based on interest rates used for recently financed projects by the AWD. Financed costs were expected to accrue in the year of implementation and then were annualized over 25 years using the specified discount rate. We also assumed a 50/50 cost share between AWD and LWD for drinking water treatment costs, per the existing agreement, except where noted below. As a result, the costs presented reflect the charges faced by the AWD and LWD and passed on to water users within both cities.

1 **Determine the objectives of the benefit-cost analysis.**
Clarify the questions the analysis seeks to answer. What decision does it seek to inform?

2 **Identify the benefits and costs.**
Clarify the potential impact of the activity and the type of benefits and costs it would generate.

3 **Value the benefits and costs.**
Express the value of benefits and costs in monetary terms. Which of these can be valued and how?

4 **Aggregate the benefits and costs.**
Discount and sum the benefits and costs over time.

5 **Perform sensitivity analysis.**
Assess the importance of major uncertainties associated with the analysis and activity.

6 **Consider distributional impacts.**
Consider who will incur the benefits and costs and what impact this might have on the activity.

7 **Prepare recommendations.**
Summarize the findings and how to proceed. Suggest what option(s) should be chosen and why.

Figure 4-1. Benefit-Cost Analysis framework (Sources: Buncle et al., 2013; Greenhalgh et al., 2017; Robinson et al., 2019).

Economic Impacts Scenarios

The following four scenarios were considered for the analysis, with scenario numbers ascending with amount of development in the watershed:

1. Existing Conditions: Maintains the current state of the watershed with no changes in ordinances or additional development.

2. Business As Usual: Simulates complete development of the watershed with no changes in ordinances.

3. Maximum Development Not Allowing Building on LAWPC Lands: Simulates complete development of the watershed with new ordinances that allow for maximum development of the watershed over time, except all LAWPC lands are still protected from development.

4. Maximum Development Allowing Building on LAWPC Lands: Simulates complete development of the watershed with new ordinances that allow for maximum development of the watershed over time, including potential conversion of all LAWPC lands to buildable land.

An overview of key benefit and cost categories for the four scenarios in the Lake Auburn watershed is provided in Table 4-1. We note that it would likely take decades for the development scenarios to achieve their specified building capacity. However, for simplicity of comparison across scenarios, we quantified the impacts assuming that they would be met immediately. Quantitative estimates of each scenario, including the aggregate net benefits, are presented in the following sections.

Note that we did not assess the economic benefits and costs of the alternative scenarios implementing low impact development strategies on new development, as presented in the Water Quality Modeling section. The only alternative scenario with a significant improvement in predicted water quality that might alter several cost assumptions was the “Maximum Development Allowing

Table 4-1. Net economic benefits and costs of four scenarios considered for the Lake Auburn watershed.

Category *	1. Existing Conditions	2. Business As Usual	3. Max Development, Not Allowing Building on LAW-PC Lands	4. Max Development, Allowing Building on LAWPC Lands
In-Lake or In-Take Water Treatment Costs				
Alum Treatment Costs	$800,000 every 10 years	No Change	No Change	No Change
Water Treatment Costs (No Filtration Plant)	$338,304/yr	Increase	Increase	$0 (covered with filtration plant)
Filtration Plant Capital Costs	None	No Change	No Change	~$40 mil every 25 years
Filtration Plant Oper. & Maint. Costs	None	No Change	No Change	$0.8 mil/yr
Filtration Plant Interest Costs	None	No Change	No Change	3% annualized discount rate on capital costs
Watershed Treatment Costs				
Watershed Restoration Costs	None	Increase	Increase	Increase
Watershed Protection Costs	$83,075/yr	Increase	Increase	Increase
Additional In-Lake/In-River Treatment Costs	None	No Change	Increase	Increase
Additional Regulatory Compliance Costs	None	No Change	Increase	Increase
City of Auburn Muncipal & Resident Costs				
Additional Costs of City Services (Auburn Only)	None	Increase	Increase	Increase
Social Equity Costs (Auburn Only)	None	Increase	Increase	Increase
City of Auburn Tax Benefits & Costs				
Tax Collected Benefits	$2.1 mil/yr	Increase	Increase	Increase
Tax Collected Loss with Water Quality Decline	None	Decrease	Decrease	Decrease
Recreation Benefits & Costs				
Swimming Benefits	Not Allowed	No Change	Increase	Increase
Swimming Area Oper. & Maint. Costs	Not Allowed	No Change	Increase	Increase
Trail Recreation Benefits	Allowed	No Change	No Change	Decrease
Snowmobiling Benefits	Allowed	No Change	No Change	Decrease
Hunting Benefits	Allowed	No Change	No Change	Decrease
Boating/Fishing Benefits	Allowed	Decrease	Decrease	Decrease
City of Lewiston Costs				
Water Treatment Cost Share	$812,999	Increase	Increase	Increase
Social Equity Costs (Lewiston Only)	None	Increase	Increase	Increase

* Figures quoted here are for the total cost of each category. The Auburn-specific economic impact estimates assumed a 50/50 share in costs between AWD and LWD, if applicable. All benefits were assumed to be accrued by the City of Auburn, Auburn water users, and/or recreators in the Auburn portion of the watershed (recreation benefits may pass to residents of both Auburn and Lewiston, as well as other surrounding municipalities).

Building on LAWPC Lands - LID" scenario, which would still result in an undesirable water quality outcome. In fact, none of the alternative scenarios with Auburn-only changes to regulations and management approaches would achieve the necessary environmental improvement at an efficient economic cost to protect Lake Auburn long-term as a primary drinking water source for the two cities. Therefore in the future, we recommend that a scenario be modeled and run through a BCA that meets the target water quality goal for Lake Auburn by expanding the existing Lake Auburn Watershed Overlay District to the headwater towns and requiring implementation of low impact development techniques on new development in the watershed. Several studies have shown that applying low impact development techniques can reduce total capital construction costs by 15% to 80% and increase property values, indicating that the benefits are likely to significantly outweigh the costs (both to the individual homeowner and public entities) (EPA, 2013; Eckart et at., 2017).

Economic Impacts Considered & Analysis Results

Alum Treatment Costs: As an in-lake management strategy for Lake Auburn, we assumed for simplicity that the need for repeated alum treatments would continue and serve as an effective means of inactivating newly deposited, phosphorus-rich bottom sediments that accumulate over time (see prior discussion under Model Scenarios section for more detail). We assumed that a similar cost of $800,000 for the 2019 partial alum treatment would be repeated once per decade. The costs of alum treatment were assumed to be financed and thus annualized over 10 years using an interest rate of 3%. Thus, the average annualized cost of conducting an alum treatment once every 10 years equates to a mean annual cost of $93,784. If costs were split 50/50 between the AWD and the LWD, then the AWD would face a cost of $46,892/yr.

Water Treatment Costs: The AWD budgeted $338,304 in FY20 for water treatment costs related to their UV treatment plant, chloramine facility, and laboratory. Previous studies have shown that the cost of water treatment escalates in watersheds that are less than 60-70% forested and generally increases by 20% for every 10% loss in forest (Morse et al. 2018; Ernst, 2004). The Lake Auburn watershed is currently 74% forested but is estimated to decline to 59% forested for the “Business As Usual” scenario and 52% forested for the “Maximum Development Not Allowing Building on LAWPC Lands” scenario, representing 20.3% and 29.7% losses in forest land cover, respectively. We estimated the increase in water treatment cost (up until a filtration plant would be needed) based on estimated increases in water treatment costs of 40.5% and 59.5% for the “Business As Usual” scenario and the “Maximum Development Not Allowing Building on LAWPC Lands” scenario, respectively (Table 4-7). As water quality declines with continued watershed development and its associated forest loss and from the effects of climate change, AWD will likely need to spend more to treat the water for consumption and to test the water to meet filtration waiver requirements. We assumed that the LWD will continue to pay an annual amount double what the AWD pays for water treatment costs due to differences in usage.

Filtration Plant Costs: We estimated the cost to construct and manage a water filtration plant by first assuming that a 12 million gallons per day (MGD) capacity facility would be needed to meet water demand. The AWD received quotes for a 12-16 MGD capacity filtration plant, for which capital costs (includes engineering and construction) ranged from $35-45 million. For comparison, we collected capacity and cost data (adjusted for inflation to 2020 dollars) from EPA (2008), as well as estimates from other Maine water districts on plants with a

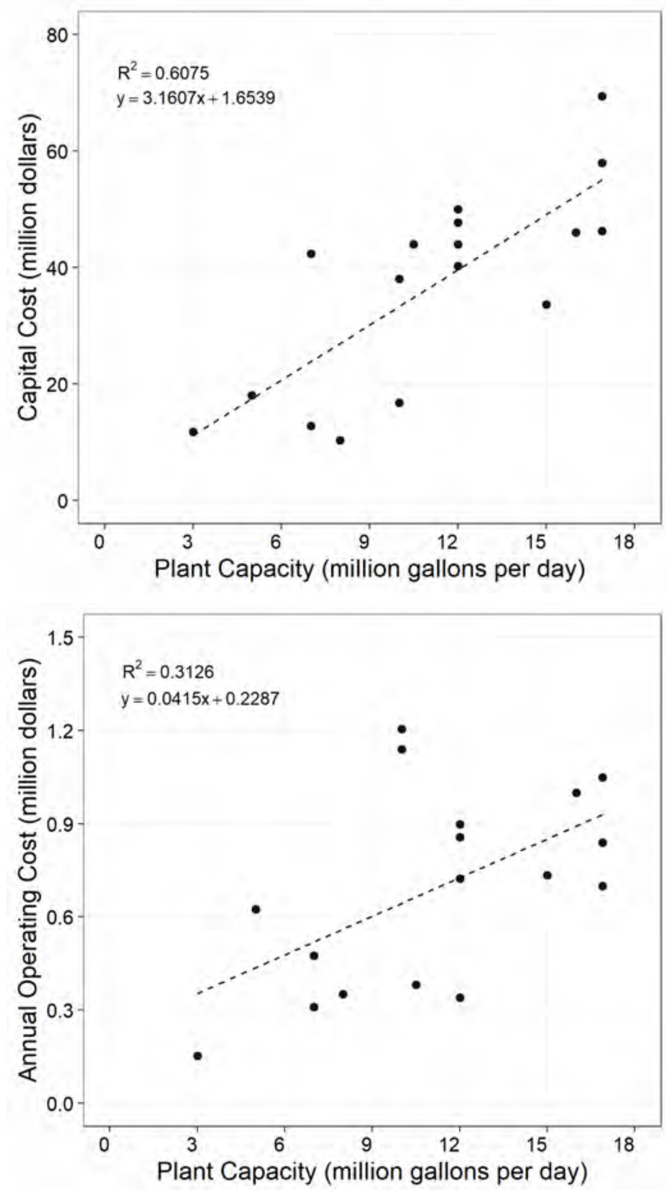

Figure 4-2. Total capital (top) and annual operating and maintenance (bottom) costs of a new filtration plant by capacity (million gallons per day, MGD), based on EPA (2008) plant data and personal communication from AWD.

capacity between 3 and 17 MGD. A total of 17 data points were used to construct a simple regression model (Figure 4-2). Using this regression, we estimated that a 12 MGD filtration plant engineered and constructed for the AWD would cost about $39.6 million, almost identical to the mean of the range of plant cost estimates provided by AWD. Applying the same methods to estimate annual operation and maintenance costs yields an estimate of $0.80 million/yr or $63.37 per million gallons treated. Spreading the capital costs of the plant across a 25-year lifespan and financing period using a discount rate of 3%, the total annualized costs of construction, operation, and maintenance for a new 12 MGD filtration plant was estimated at $3.07 million/yr. If the filtration plant costs were split 50/50 between the two water districts, then the AWD would face a cost of $1.54 million/yr.

Watershed Restoration Costs: Increased development is not only expected to reduce drinking water quality but also create higher levels of nonpoint source pollution that will need to be mitigated through a mix of watershed restoration activities (Shortle and Horan, 2017; Fleming et al., 2019). All three future scenarios predicted water quality in Lake Auburn that would be considered impaired under current state standards. For context, with assistance from a Clean Water Act Section 319 Watershed Assistance Grant, LAWPC contributed nearly $265,000 in 2015-16 for watershed improvement projects, such as constructing buffers and culverts to remediate a few erosion problems in the watershed and reduce the annual total phosphorus load by 2.1 kg/yr (LAWPC, 2016). Potential future restoration projects could take the form of planting vegetated buffers around Blanchard Pond (Tighe & Bond, 2021) or re-engineering stormwater drainage from Route 4 to drain away from Lake Auburn's watershed. Given the wide variety of projects that could be necessary (and the wide cost range), we took a simplified approach and assumed a ratio of $139,292 per 1 kg of phosphorus removed, as calculated from the 2015-16 effort and adjusted for inflation to 2020. The water quality model showed that 57 kg/yr, 94 kg/yr, and 177 kg/yr of total phosphorus load removal would be needed to meet a target total phosphorus load of 900 kg/yr for the "Business As Usual", "Maximum Development Not Allowing Building on LAWPC Lands", and "Maximum Development Allowing Building on LAWPC Lands" scenarios, respectively. The cost was financed and annualized over a 25-year period. We then applied a 50/50 cost share with the City of Lewiston.

Watershed Protection Costs: Watershed protection costs generally can include a wide range of watershed water quality protection activities, practices, studies, and improvements. In the Lake Auburn watershed, this cost category reflects the activities of LAWPC. The AWD budgeted $65,000/yr for the watershed protection line item in 2020. Actual expenditure on protection between 2017 and 2020 ranged from $68,550 to $108,380. Averaging over the 4-year period yields a mean annual watershed protection cost of $83,075/yr. Increased development is likely to intensify watershed protection activities and thus increase the cost of watershed protection, which we assumed could go up by as much as 300% over the recent mean annual costs, with costs varying by the intensity of development and in-lake water quality. As such, we assumed that these costs would increase by 50% for the "Business As Usual" scenario, 150% for the "Maximum Development Not Allowing Building on LAWPC Lands" scenario, and 300% for the "Maximum Development Allowing Building on LAWPC Lands" scenario. We assumed that the LWD pays a matching annual amount to LAWPC for watershed protection costs.

Additional In-Lake/River Treatment Costs: Higher nutrient loads predicted under increased development and exacerbated by climate change in future scenarios will require higher costs for internal and external nutrient load reductions to meet regulatory requirements for in-lake water quality (regardless of drinking water quality at the water utility in-take). In addition to the nutrient reductions afforded by the assumed repeated in-lake partial alum treatments (see prior discussion under Model Scenarios section for more detail), we assumed that additional in-lake and in-river treatment for total phosphorus load reduction and/or habitat improvement would be necessary under the two maximum development scenarios. Our analysis used the information provided by Dr. Ken Wagner in his review of several additional in-lake and in-river phosphorus control technologies/approaches (WRS, Inc., 2019): in-lake hypolimnetic oxygenation systems and in-river alum dosing stations.

We assumed that hypolimnetic oxygenation systems would be needed under the two maximum development scenarios to reduce bottom-water anoxic periods that would otherwise 1) trigger releases of internal phosphorus load from the lake sediment and 2) severely reduce critical habitat for fish and other aquatic species. Essentially, these systems pump oxygen bubbles into bottom waters to keep dissolved oxygen levels above 2 mg/L, thus preventing the chemical reactions that can release phosphorus when oxygen is severely depleted while also allowing sensitive aquatic species to survive in cooler bottom waters during the summer months. We used Dr. Wagner's estimated costs (capital costs of $2.5 million and annual operation costs of $395,000/yr), financed over a 25-year period and annualized to $704,204. We then applied a 50/50 cost share with the City of Lewiston.

We assumed that tributary alum dosing stations would be needed to reduce the incoming total phosphorus load to the lake to achieve additional external nutrient load reductions from the watershed for both the maximum development scenarios. WRS, Inc. (2019) estimated $40,000/yr to maintain two alum dosing stations on each of the major tributaries to Lake Auburn, Townsend Brook and the Basin inlet (in addition to an upfront capital cost of roughly $100,000 each), to inactivate large storm-generated phosphorus loads into the lake. Specifically, we assumed that tributary alum dosing stations would be installed at the inlets of Townsend Brook and the Basin and used Dr. Wagner's estimated costs annualized (not financed) over a 60-year period (with station replacement or upgrade similar to capital costs every 10 years), totaling $60,000/yr for the two stations. We then applied a 50/50 cost share with the City of Lewiston.

Additional Regulatory Compliance Costs: Regulatory compliance costs for lakes and lake watersheds can take many forms, including permitting costs, plan development costs (e.g., Total Maximum Daily Load plans), legal fees, consent decrees, and compliance monitoring. This list is not exhaustive, the potential costs are quite uncertain, and the time and effort expended by municipal and utility staff navigating the regulatory complexities are considerable. We assumed that declining water quality in the two maximum development scenarios would incur additional regulatory costs. We used best professional judgment to estimate the costs, with a maximum annual cost of $400,000 applied to the "Maximum Development Allowing Building on LAWPC Lands" scenario. We then applied a 50/50 cost share with the City of Lewiston.

Additional Costs of City Services (Auburn Only): We assumed that additional development in the Lake Auburn watershed will impose additional costs to the City of Auburn through expansion of City services to new residents. City services cover public road and stormwater infrastructure maintenance, police, fire, and ambulance services, and administrative and other staff resources. These costs are often referred to as the 'Cost of Community Services' (COCS), which are estimated to compare the ratio of expenditures-to-revenues for different land uses and are often influential in debates about municipal land-use planning. While conducting a formal COCS was beyond the scope of this study, recent assessments indicate that every $1 that residential properties generate in revenue typically costs at least $1 in services, while commercial, industrial, agricultural, and open-space land uses tend to have revenue-cost ratios less than one, meaning that those land uses cost less than they generate in revenue (Kotchen and Schulte, 2009; Farmland Information Center, 2016).

For this study, we took a conservative approach and used a COCS ratio of $0.20 in service costs for every additional $1.00 of property tax collected. The conservative assumption was taken because much of the development is expected to occur along existing roads and infrastructure, and the relatively older age of the City's population means that there may not be a large influx of school-age residents. As a result, Auburn's city service costs would increase by $0.24-1.07 million/yr over the current, with the greatest increases occurring in the "Maximum Development Allowing Building on LAWPC Lands" scenario. No cost share was applied to LWD, as these costs would be borne 100% by the City of Auburn.

Property Tax Collection Benefits: Properties located within the City of Auburn portion of the Lake Auburn watershed currently pay about $2.1 million per year in taxes. The total amount of tax collected increases with additional development, as more residential and commercial properties are constructed. For this analysis, we assumed that most new development would be single-family homes, for which the property value was based on the average value of the same land use class category (e.g., single-family residential) of properties currently situated in the watershed, per the 2019 Auburn parcel and tax map. We also assumed that the current mill rate of 23.75 per $1,000 of valuation is applied to the property. Benefits were estimated as the net increase in tax collected relative to 2019.

Total property value in Auburn was estimated at $2.17 billion dollars for 2020 (Table 4-2). More than 70% of the value was attributed to buildings, followed by land (25%) and yards (4%). About $153.3 million (7.1%) of that total value was in the Lake Auburn watershed, which accounts for 25% of the City's total land area (Figure 4-3). In 2020, approximately $3.6 million of property tax was generated from properties located in the Lake Auburn watershed. For context, the City of Auburn's FY 20-21 total annual budget was $92 million.

If property development were to follow the three future scenarios, then the number of buildings to value in the Lake Auburn watershed would increase from the current level of 422 to between 661 and 1,382 buildings (Table 4-3, Figure 4-4). The developed parcels would be valued higher than their previous use, so the overall valuation would increase as well. We estimated that total valuation in the Lake Auburn watershed would increase by 33-147% over existing conditions. If the current mill rate of 23.75 per $1,000 valuation is applied to all properties, then total

Table 4-2. City of Auburn tax valuation for 2020.

Category	City of Auburn	Lake Auburn Watershed	% Lake Auburn of All Auburn
Land Area (acres)	57,756	14,710	25%
Land Valuation ($)	$519,904,976	$36,289,376	7.0%
Yard Valuation ($)	$99,602,000	$4,228,600	4.2%
Building Valuation ($)	$1,552,589,505	$112,752,500	7.3%
Total Property Valuation ($)	$2,172,096,481	$153,270,476	7.1%
Approx. Tax Collected ($/yr)*	$51,587,291	$3,640,174	7.1%

*Assuming mill rate of 23.75 per $1,000 of valuation applied to all properties

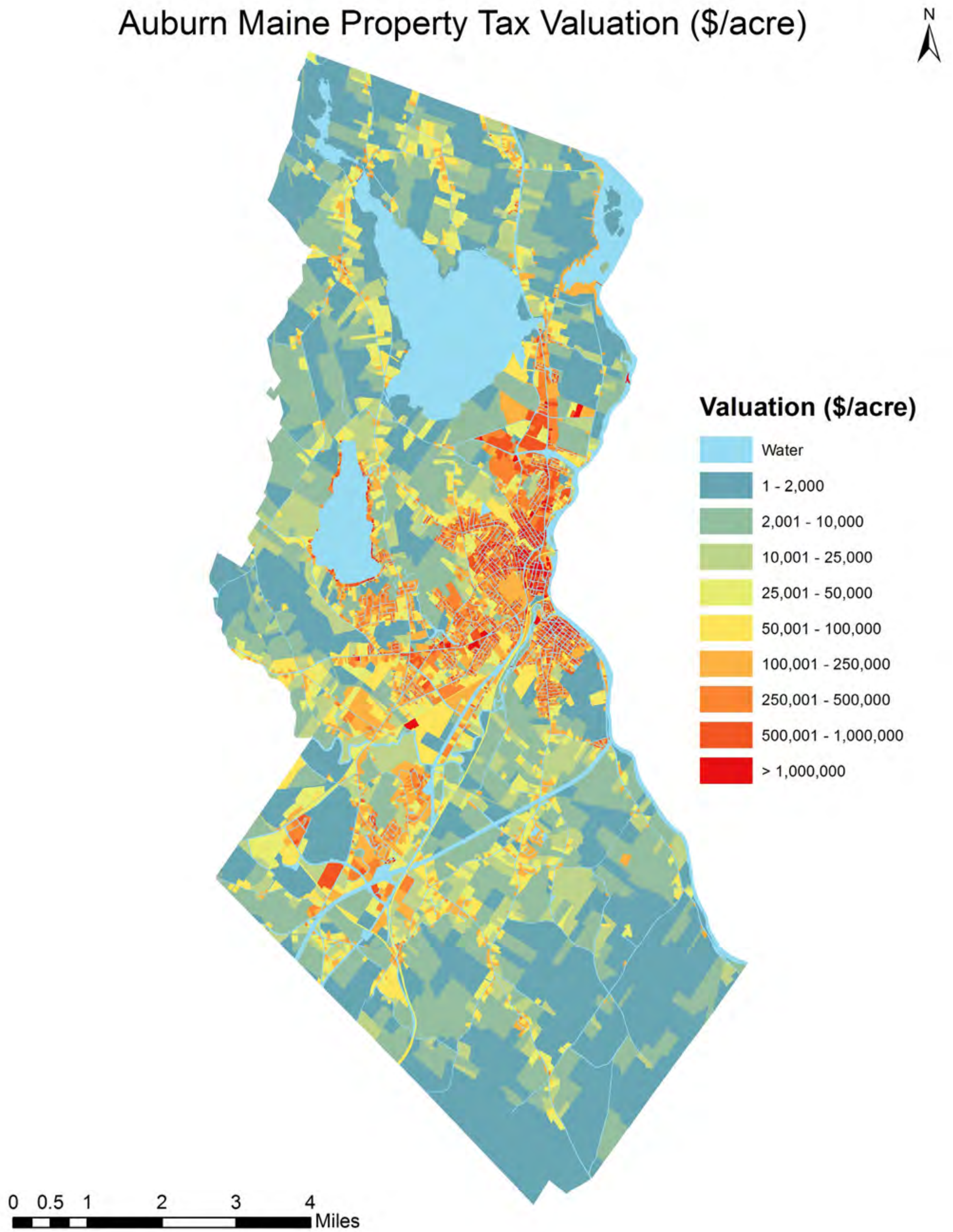

Figure 4-3. City of Auburn 2020 property valuation ($/acre). Map created by A. Daigneault, UMaine.

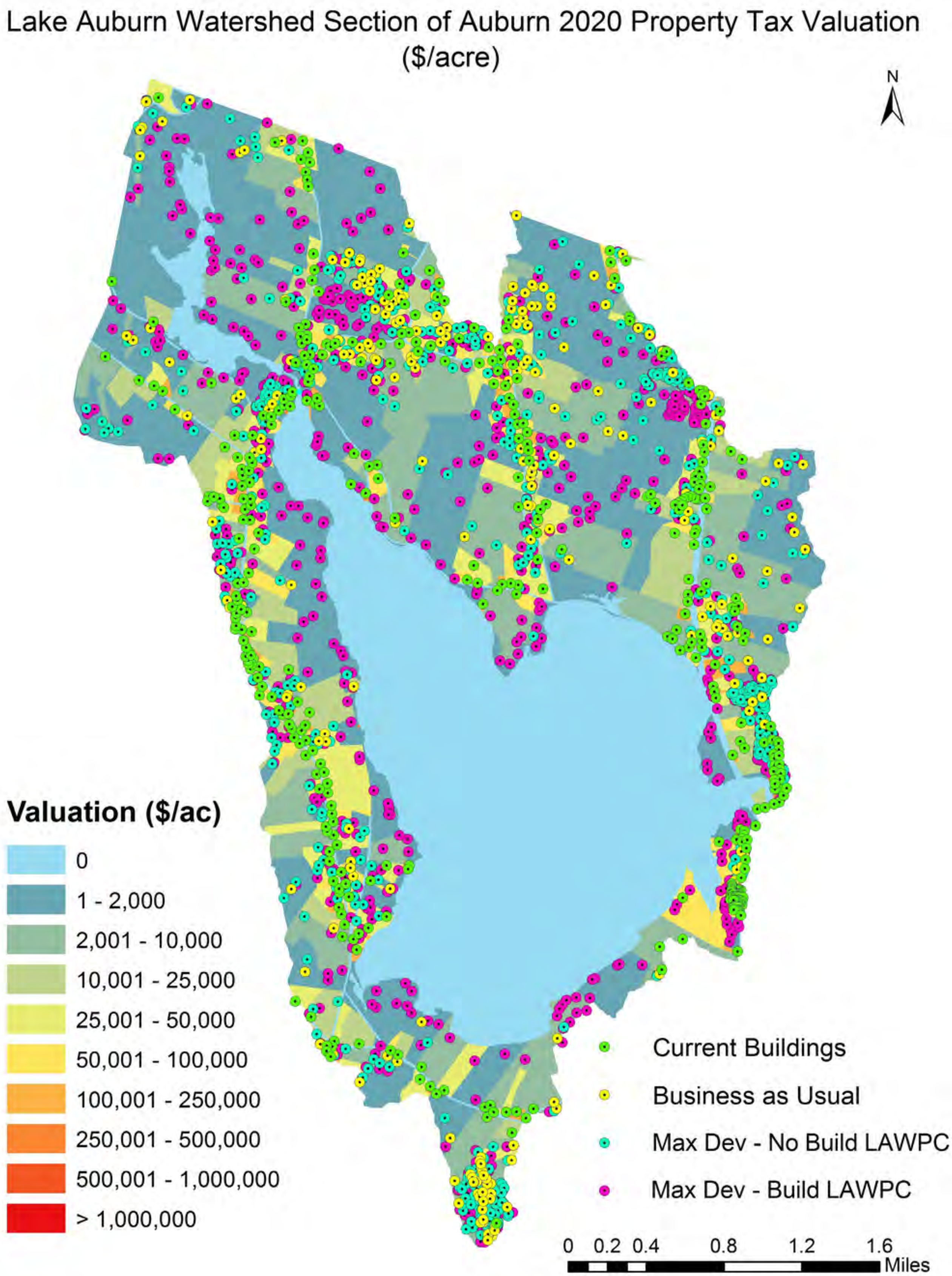

Figure 4-4. Auburn portion of the Lake Auburn watershed 2020 property valuation ($/acre) and building location by development scenario. Map created by A. Daigneault, UMaine.

Table 4-3. Lake Auburn watershed development, valuation, and tax collection estimates.

Category	1. Existing Conditions	2. Business As Usual	3. Max Development Not Allowing Building on LAWPC Lands	4. Max Development Allowing Building on LAWPC Lands
Total developed parcels	422	661	1,009	1,382
Change from current parcels	0	239	587	960
% change from current parcels	0%	57%	139%	227%
Total property valuation	$153,270,476	$203,735,680	$294,087,194	$377,980,555
Tax collected	$3,640,174	$4,838,722	$6,984,571	$8,977,038
Tax Loss with Water Quality Decline	$0	-$7,156	-$8,120	-$50,355
Net change from current tax	$0	$1,191,392	$3,336,277	$5,286,509
% change from current tax	0	33%	92%	145%

valuation would result in $1.2 to $5.3 million/yr in additional tax revenue collected from new development in the Lake Auburn watershed.

However, we then adjusted the tax collected benefits to account for likely declines in property value as a result of declines in water clarity under the three future scenarios. Based on a study of 36 lakes in four regional groups in Maine, Boyle & Bouchard (2003) found that shorefront property values can decrease by up to 8.5% for a one-meter decline in water clarity. An empirical formula for Secchi disk transparency (i.e., water clarity; Oglesby & Schaffner, 1978) predicted a reduction in water clarity by 0.5 m, 0.6 m, and 0.8 m for the "Business As Usual", "Maximum Development Not Allowing Building on LAWPC Lands", and "Maximum Development Allowing Building on LAWPC Lands" scenarios, respectively, compared to "Existing Conditions" post-alum treatment. Applying this method to just the 23 shorefront properties in scenarios that keep LAWPC lands undeveloped and the 114 properties in the "Maximum Development Allowing Building on LAWPC Lands" scenario results in annual tax collected loss estimates associated with lower water quality of $7,156, $8,120, and $50,355 for the "Business As Usual", "Maximum Development Not Allowing Building on LAWPC Lands", and "Maximum Development Allowing Building on LAWPC Lands" scenarios, respectively. These losses likely represent conservative estimates but can also be highly variable due to the valuation methods that the City of Auburn applies and our assumption of using the current mean residential property valuation for future developed parcel valuations.

Recreation Benefits and Costs: A commonly used measure in resource allocation debates is economic value. Economic value measures the personal or intrinsic value held by users of a resource or people affected by an action or item. This term essentially measures the quality-of-life effects or how much one is better or worse off intrinsically from taking part in a recreation activity. For example, a person may spend $100 in time and travel costs to go fishing, but the trip was worth $125 intrinsically to that individual. That person was better off by $25 after taking the trip, and $25 is the net economic value of the trip. Note that this method is different from estimating direct and indirect economic impacts via quantifying the specific expenditures associated with the activity (e.g., bait, bikes, lodging, etc.). We chose to use the 'economic value' approach because it likely better reflected the typical Lake Auburn watershed recreator. That is, most recreators were likely to be from nearby, recreate for relatively short periods of time, and have little to no expenditures as a result.

For this analysis, we estimated recreation benefits for swimming, boating, fishing, and human powered trail-based activities like hiking and biking, snowmobiling, and hunting. The economic values in this analysis were derived using a method known as 'benefits transfer', or "values transfer" (Johnston and Wainger, 2015), which has been frequently used in ecosystem service assessments (e.g., de Groot et al., 2012; Costanza et al., 2014) and economic analyses of natural resource management projects (e.g., Wang et al., 2017). The commonly applied methodology uses secondary data from studies that focused on areas with similar climatic and socioeconomic conditions as the Lake Auburn watershed (Troy et al., 2012). For this study, estimates were derived from prior studies conducted in Maine, the Northeast and Mid-Atlantic US, and Eastern Canada. To quantify the specific values, we conducted a literature search for the specified geographical constraints using five ecosystem service valuation databases (Environmental Valuation Reference Inventory (EVRI), 2020; Ecosystem Services Valuation Database (ESVD), 2020; USGS Benefit Transfer Toolkit, 2020; Natural Assets Information System (NAIS), 2018; Recreation Use Values Database (RUVD), 2020). These values vary depending on the study focus, methodology, and location. Further, the value of the recreation experience is

Table 4-4. Range of values applied to estimate the economic impacts of recreation opportunities in the Lake Auburn watershed.

Recreation Type	Unit	Economic Value ($/unit)		
		Low	Medium	High
Swimming	Day trips	$8	$17	$25
Boating / Fishing	Lake acres	$174	$261	$348
Trail Recreation	LAWPC acres	$177	$265	$397
Snowmobiling	Trail miles	$16,000	$24,000	$36,000
Hunting	LAWPC acres	$34	$51	$77

likely to vary by quality and experience (e.g., poor water quality is likely to reduce the time and value spent boating and/or fishing on the lake). As such, we utilized the various sources noted above to specify a range of values that could be applied to recreation opportunities in the Lake Auburn watershed (Table 4-4). A nearly identical methodology was used to quantify the economic benefits derived from forest conservation in the Sebago Lake watershed (Daigneault et al., 2021).

Recreation values for boating and fishing activities were based on the total area of Lake Auburn (2,260 acres). Trail hiking and biking activities were determined by the area of LAWPC land and conservation easements in the Auburn portion of the Lake Auburn watershed (currently 1,863 acres). Swimming benefits were estimated based on the number of daily visitors that could swim at a proposed restricted beach access area, which was assumed to accommodate up to 150 people per day (with only 50 people allowed at one time) and be open 90 days a year. Hunting values were based on the total area of land on which LAWPC allows hunting access (1,273 acres). Note that LAWPC permits hunting with firearms on 1,053 of these acres, while bow hunting is allowed on an additional 220 acres. We assumed that firearm and bow hunting received the same value, which is measured in $/acre/yr. About 8.32 miles of snowmobile trails run through publicly accessible land in the Lake Auburn watershed. A recent analysis using total economic impact figures from the Maine Snowmobile Association estimated that Maine's snowmobile trails produce a mean annual value of about $24,000/mile/yr (Daigneault and Strong, 2018).

Each scenario was expected to impact the economic value of recreation opportunities in the Lake Auburn watershed. The impacts can vary by both quality and area available to recreate. For example, opening a restricted area for swimming will increase that recreation opportunity, but the value of the activity could vary with water quality. Alternatively, if LAWPC lands are not protected and thus developed, then they would not be available to provide the same trail-based recreation, snowmobiling, or hunting opportunities. The economic impacts for these recreation opportunities in the Lake Auburn watershed – noting that fishing and boating were lumped together as a combined on-water activity – are listed in Table 4-5.

Swimming was estimated to produce an annual economic value of $0-$229,500/yr, with the highest total value occurring in the "Maximum Development Not Allowing Building on LAWPC Lands" scenario under which water quality was fair and swimming was permitted. Conversely, the "Maximum Development Allowing Building on LAWPC Lands" scenario was only expected to provide $54,000/yr because water quality was predicted to be poor, thereby reducing both the economic value per visit, as well as the number of visitors. We also included an approximation of the operation and maintenance cost to allow swimming in Lake Auburn, estimated at $100,000/yr. To properly maintain the swimming area and enforce stringent swimming area rules, the City (in coordination with the AWD and LAWPC) would be responsible for the additional paid staff time for daily presence and enforcement, seasonal swimming area maintenance, restroom facility operation and maintenance, and additional water quality testing. The inclusion of these costs results in a reduced net benefit for the "Maximum Development Not Allowing Building on LAWPC Lands" scenario and a net loss for the "Maximum Development Allowing Building on LAWPC Lands" scenario. We assumed that the proposed swimming area would only be open to Auburn residents.

On-lake activities permitted on Lake Auburn, such as boating and fishing, were estimated on a per acre basis encompassing the entire area of the lake (2,260 acres). We estimated that this recreation activity generates an economic value of $393,240 to $786,480/yr. The "Maximum Development Allowing Building on LAWPC Lands" scenario was estimated to generate the lowest value due to noticeable reductions in water quality that diminish the utility of recreating on the lake. Existing conditions in the Lake Auburn watershed generated the highest value from boating and fishing because of the current high quality of the lake water.

Trail-based recreation in the watershed was also valued on a per acre basis and was largely determined by the area of publicly accessible protected land. This activity generated between $66,299 and $493,695/yr in economic value. Benefits associated with hiking, walking, and mountain biking were expected to be the same for the "Existing Conditions", "Business As Usual", and "Maximum Development Not Allowing Building on LAWPC Lands" scenarios, as there was no change in LAWPC land area. However, the conversion of nearly 1,700 acres of LAWPC land to development in the "Maximum Development Allowing Building on LAWPC Lands" scenario results in a large loss in area available for recreation, and thus the value declines by more than $427,000/yr (-87%),

Table 4-5. Recreation benefits for four scenarios in the Auburn portion of the Lake Auburn watershed.

Category	Swimming (day trips)	Boating / Fishing (acres)	Trail Recreation (acres)	Snowmobiling (miles)	Hunting (acres)
1. Existing Conditions					
Unit	0	2,260	1,863	8.32	1,273
Economic Value ($/unit)	$0	$348	$265	$24,000	$51
Total Value ($/yr)	$0	$786,480	$493,695	$199,680	$64,923
2. Business As Usual					
Unit	0	2,260	1,863	8.32	1,273
Economic Value ($/unit)	$0	$261	$265	$24,000	$51
Total Value ($/yr)	$0	$589,860	$493,695	$199,680	$64,923
3. Max Development Not Allowing Building on LAWPC Lands					
Unit	13,500	2,260	1,863	8.32	1,273
Economic Value ($/unit)	$17	$261	$265	$24,000	$51
Total Value ($/yr)	$229,500	$589,860	$493,695	$199,680	$64,923
4. Max Development Allowing Building on LAWPC Lands					
Unit	6,750	2,260	167	6.92	0
Economic Value ($/unit)	$8	$174	$397	$24,000	$0
Total Value ($/yr)	$54,000	$393,240	$66,299	$166,080	$0

even when the per acre value of the remaining accessible land was assumed to increase due to the scarcity effect.

Snowmobiling can provide up to $200,000/yr in economic benefits via the use of 8.32 miles of trails that run through the watershed, including the 1.4 miles on LAWPC lands. Implementing the "Maximum Development Allowing Building on LAWPC Lands" scenario would remove access to the 1.4 miles of LAWPC trails and likely result in lost connectivity of the remaining trails outside of LAWPC land which would need to be reconnected on private land.

Firearm and/or bow-based hunting is allowed on 1,273 acres of LAWPC land in the watershed. These lands provide nearly $65,000/yr in economic benefits. Implementing the "Maximum Development Allowing Building on LAWPC Lands" scenario would restrict all access to these hunting areas, thereby eliminating this benefit.

<u>Costs to Lewiston</u>: This analysis centers on economic impacts to the City of Auburn, its taxpayers, and AWD ratepayers, but external economic impacts should also be considered for other key stakeholders to adequately account for the distributional impacts of the different scenarios. Any analysis of the economics of Lake Auburn would be incomplete without considering the impacts to the City of Lewiston, its taxpayers, and LWD ratepayers. We did this by calculating the total estimated costs derived from all line items with cost sharing, and then evaluating the increased costs to Lewiston over "Existing Conditions". Most line items with cost sharing were split 50/50, but water treatment costs were split based on usage. For those costs, we used a 2:1 cost share, with Lewiston paying double what Auburn pays. The water treatment costs line item goes away for the "Maximum Development Allowing Building on LAWPC Lands" scenario and is replaced by the line items for filtration plant capital, operation and maintenance, and financing costs, which were assumed to be a 50/50 cost share. Net Economic Impact to Lewiston Only is not estimated because the benefits we considered are either specific to the City of Auburn (e.g., property taxes collected) or general to Auburn and surrounding areas (e.g., recreation benefits) with Lewiston receiving a share that is difficult to quantify and unlikely to have a significant counterbalancing effect on the costs incurred.

<u>Drinking Water Consumption Costs to Auburn/Lewiston Water Consumers</u>: A key stakeholder in this economic analysis is the ratepayer of both AWD and LWD. These ratepayers are the consumers of Lake Auburn drinking water who would be assuming much of the additional cost burden associated with the three future scenarios, as costs to maintain high quality drinking water increase with the intensity of development allowed. We estimated that the current average annual water bill of $255/yr for

Table 4-6. Estimated impacts of Auburn and Lewiston household drinking water rates by scenario. Scenarios are assumed to project out to 2100. (cf = cubic feet)

Category	1. Existing Conditions	2. Business As Usual	3. Max Development Not Allowing Building on LAWPC Lands	4. Max Development Allowing Building on LAWPC Lands
		Auburn Water District (AWD)		
Total Water Treatment Related Costs*	$468,271	$873,117	$1,646,789	$3,115,755
Other AWD Costs (no change)^	$2,086,801	$2,093,225	$2,093,225	$2,093,225
Total Water Meter Revenues to Balance Costs†	$2,561,496	$2,966,342	$3,740,014	$5,208,980
Increase in Auburn Water Rates (%)	**0%**	**16%**	**46%**	**103%**
Average Auburn Water Rate Charges ($/100 cf)‡	**$3.63**	**$4.20**	**$5.30**	**$7.38**
Average Annual Auburn Household Water Bill	**$255**	**$295**	**$372**	**$519**
		Lewiston Water Division (LWD)		
Total Water Treatment Related Costs*	$812,999	$1,354,995	$2,192,671	$3,122,179
Other LWD Costs (no change)^	$3,862,444	$3,862,444	$3,862,444	$3,862,444
Total Water Meter Revenues to Balance Costs†	$4,675,443	$5,217,439	$6,055,115	$6,984,623
Increase in Lewiston Water Rates (%)	**0%**	**12%**	**30%**	**49%**
Average Lewiston Water Rate Charges ($/100 cf)‡	**$4.26**	**$4.75**	**$5.52**	**$6.36**
Average Annual Lewiston Household Water Bill	**$340**	**$379**	**$440**	**$508**

* See Table 4-7 for detailed costs
^ Other costs held constant across all scenarios, assuming no change besides water treatment related costs
† Assumed water meter revenues were balanced with total costs of treatment and other drinking water-related costs
‡ Based on average use of 2,000 cf/quarter

AWD ratepayers would increase to $295, $372, and $519/yr for the "Business As Usual", "Maximum Development Not Allowing Building on LAWPC Lands", and "Maximum Development Allowing Building on LAWPC Lands" scenarios, respectively (Table 4-6). This translates to a 16-103% increase in annual household water bills for Auburn residents, for which the average water rate charge for 2,000 cubic feet (cf) per quarter could increase from $3.63/100 cf to as much as $7.38/100 cf. Similarly, we estimated that the current average annual water bill of $340/yr for Lewiston ratepayers would increase to $379, $440, and $508/yr for the same respective scenarios as Auburn, a 12-49% increase over current rates. This is equivalent to a water rate hike from $4.26/100 cf to $6.36/100cf for an average Lewiston household that uses 2,000 cf per quarter. For context, AWD consumers experienced a 13.7% increase in water rates in 2020, while a 23% rate hike for LWD consumers was recently approved to take effect in FY22.

According to data from the Maine Public Utilities Commission (2019), the AWD is currently ranked in the 90th percentile in terms of average household drinking water costs in Maine (i.e., only 10% have lower costs), while LWD is ranked in the 75th percentile after the recent rate hike. Increasing water rates to offset the higher costs associated with needing a filtration plant would move the AWD and LWD water costs to the 25th and 40th percentile, respectively. Note, data for each water utility was last updated in May 2019. We adjusted the AWD and LWD costs to reflect their latest water rates.

Social Costs of Increased Drinking Water Costs: Increases in household water bills will have a distributional impact on the affordability of drinking water, with a larger impact on customers with low and/or fixed incomes. To cope with these increased costs, some customers are likely to cut back on other essential household expenses such as rent, transportation, medical care, fresh produce, or school supplies. The US EPA indicates that drinking water is considered affordable if the annual costs are less than 2.5% of household income (EPA, 2002). Currently, an average AWD (LWD) water bill would account for 1.2% (1.5%) of a 3-person household living on an annual income at the poverty line ($21,960), while the increased rates associated with the "Maximum Development Allowing Building on LAWPC Lands" scenario would increase the proportion to 2.4% (2.3%). While these higher household water costs are still below the EPA affordability threshold for a household living at the poverty threshold, it is logical to expect that some additional social costs could accrue as a result of tighter household budgets, including increased stress, diminished health, and the loss in productivity associated with these impacts. While we were unable to source a reasonable estimate of the added social costs associated with an increase in water bills for this study, we indicate in Table 4-7 that it is likely to be greater than $0 for both Auburn and Lewiston.

Aggregate Economic Impacts

The aggregate economic impacts of the four scenarios – measured in annualized values per annum – are listed in Table 4-7. Net economic impacts were measured as total tax and recreation benefits less the water treatment and protection costs. All four scenarios yielded net economic benefits to the City of Auburn ranging from $4.7 to $6.1 million/yr, with net change from "Existing Conditions" ranging from $0.4 to $1.4 million/yr. However, there are significant distributional impacts across the two cities to consider. While Auburn could receive net benefits from expanded development in the watershed, some of the costs of doing so are passed along to the City of Lewiston and LWD ratepayers. The added costs associated with declining water quality borne by Lewiston are considerable, ranging from $0.5 to $2.3 million/yr. In two of the future scenarios, the net cost increase to Lewiston was greater than the net benefit to Auburn; for the third future scenario ("Maximum Development Not Allowing Building on LAWPC Lands"), a minimal net benefit for both cities was determined but was considered within the "noise" or variability of the cost assumptions made, meaning that the small net benefit could easily become a net cost for that scenario.

In summary, expanding development in the Lake Auburn watershed provides minimal net economic benefit across all affected stakeholders.

In summary, we determined that expanding development in the Lake Auburn watershed provides minimal net economic benefit across all affected stakeholders. Although the maximum development scenarios were estimated to generate greater revenue for Auburn from property taxes on additional development, the increased costs associated with City services for each new home coupled with loss of recreation values and greater efforts to meet drinking water standards due to poor water quality offset the additional tax revenue accrued. Further, many of our estimates were conservative and may not capture the true cost of additional City services and watershed protection and restoration efforts for the Lake Auburn watershed.

Photo Credit: Portland Press Herald

Table 4-7. Economic impacts of the Lake Auburn watershed scenario analysis (annualized $/yr).

Category of Annualized Cost/Benefit	1. Existing Conditions	2. Business As Usual	3. Max Development Not Allowing Building on LAWPC Lands	4. Max Development Allowing Building on LAWPC Lands
Alum Treatment Costs*	$46,892	$46,892	$46,892	$46,892
Water Treatment Costs (No Filtration Plant)†	$338,304	$475,454	$539,458	$0
Filtration Plant Capital Costs ‡	$0	$0	$0	$792,000
Filtration Plant Oper. & Maint. Costs ‡	$0	$0	$0	$400,000
Filtration Plant Interest Costs ‡	$0	$0	$0	$345,072
Watershed Restoration Costs**	$0	$226,158	$370,650	$700,464
Watershed Protection Costs ††	$83,075	$124,613	$207,688	$249,225
Additional In-Lake/River Treatment Costs ‡‡	$0	$0	$382,102	$382,102
Additional Regulatory Compliance Costs***	$0	$0	$100,000	$200,000
Additional Costs of City Services (Auburn Only)****	$0	$239,710	$668,879	$1,067,373
Social Equity Costs (Auburn Only)^	$0	> $0	> $0	> $0
Tax Collected Benefits	$3,640,174	$4,838,722	$6,984,571	$8,977,038
Tax Collected Loss with Water Quality Decline^^	$0	-$7,156	-$8,120	-$50,355
Swimming Benefits †††	$0	$0	$229,500	$54,000
Swimming Area Oper. & Maint. Costs	$0	$0	-$100,000	-$100,000
Trail Recreation Benefits	$493,695	$493,695	$493,695	$66,299
Snowmobiling Benefits	$199,680	$199,680	$199,680	$166,080
Hunting Benefits	$64,923	$64,923	$64,923	$0
Boating/Fishing Benefits	$786,480	$589,860	$589,860	$393,240
Total Costs (Auburn Only)	**$468,271**	**$1,112,826**	**$2,315,669**	**$4,183,128**
Total Benefits	**$5,184,952**	**$6,179,724**	**$8,454,109**	**$9,506,302**
Net Economic Impacts (Auburn Only)	**$4,716,681**	**$5,066,898**	**$6,138,441**	**$5,323,175**
Net Change from Current (Auburn Only)	**$0**	**$350,217**	**$1,421,760**	**$606,494**
Water Treatment Cost Share (Lewiston Only) ‡‡‡	$806,575	$1,348,571	$2,186,247	$3,115,755
Social Equity Costs (Lewiston Only)^	$0	> $0	> $0	> $0
Net Cost Increase to Lewiston Over Current	**$0**	**$541,996**	**$1,379,672**	**$2,309,180**
Net Economic Impact (Auburn & Lewiston)	**$0**	**-$191,779**	**$42,088**	**-$1,702,686**

* Alum treatment costs are estimated for all scenarios based on the Lake Auburn 2019 partial alum treatment cost; assumed 8 treatments (every 10 years through 2100) financed and annualized over 10-year periods using a 50/50 cost share.
† Water treatment costs include operations and maintenance of the existing UV treatment plant, chloramine facility, and testing laboratory in Auburn and were estimated using current budgetary information and forecasted for the three future scenarios using relationships from published literature (20% increase in treatment costs for every 10% loss in forest land in the watershed). Cost sharing is based on usage: 2:1 for LWD:AWD.
‡ Filtration plant capital costs, financing costs, and operation and maintenance costs were estimated based on case study examples and were annualized over 25 years using a 50/50 cost share.
** Watershed restoration costs (for phosphorus load reduction/stormwater control improvements) were estimated assuming $139,292 per 1 kg of phosphorus removed for the estimated phosphorus load reduction needed to meet a target phosphorus load of 900 kg/yr for the three future scenarios. Costs were financed and annualized over a 25-year period, and a 50/50 cost share was applied.
†† Watershed protection costs (for activities of the Lake Auburn Watershed Protection Commission) were estimated based on a 4-year mean annual cost and adjusted by the percent increases in development for each future scenario, assuming a 50/50 cost share.
‡‡ Additional in-lake/river treatment costs (for additional internal and external phosphorus load reductions) followed WRS, Inc. (2019) and incorporated a 50/50 cost share.
*** Additional regulatory compliance costs (for managing additional water quality regulatory compliance) were estimated based on best professional judgement, using a 50/50 cost share.
****Additional Costs of City Services (Auburn Only) assumed a conservative ratio of $0.20 in service costs for every additional $1.00 of property tax collected.
^ Social costs associated with higher water bills for low and fixed income households include increased stress, diminished health, and the loss in productivity associated with these impacts. We were unable to monetize these impacts for the study but recognize that they will be greater than $0.
^^ A decline in water quality has been shown to reduce shorefront household values, which would therefore reduce the amount of property taxes .
††† Swimming benefits were not included for the "Business As Usual" scenario because this scenario assumes no changes to current rules.
‡‡‡Costs to Lewiston compiled all cost sharing from above line items, including costs to the City of Lewiston, its taxpayers, and its water ratepayers. Recreation benefits that may also apply to Lewiston residents are accounted for in the Net Economic Impacts to Auburn Only.

5 Findings, Synthesis, & Holistic Recommendations

This section draws out key conclusions from the report's preceding Sections 2, 3, and 4 which contain our analyses of the regulatory, environmental, and economic impacts of Lake Auburn as a public drinking water supply. Synthesis and further discussion, along with consideration of examples from comparable water supplies, are also provided for several key conclusions that recur throughout the preceding sections. Lastly, this section puts forth holistic recommendations for the City of Auburn, as well as the broader community of stakeholders, with the aim of promoting water supply protection efforts and initiatives that preserve or improve the balance among regulatory, environmental, and economic impacts.


Photo Credit: Sun Journal

Key Findings

Section 2, Analysis of Regulatory Impacts

We found that the regulatory framework for the protection of Lake Auburn as a water supply can be revised to be more clearly defined, better aligned with the best available science and State and regional norms, and more fairly applied across different land uses and activities. Specific recommendations are described in depth in Section 2, and direct ordinance language revisions are provided in a separate document to the City. A summary of our recommended revisions is outlined below:

- Revise the septic system requirements of the Lake Auburn Watershed Overlay District Ordinance to incorporate the Maine Subsurface Wastewater Disposal Rules, including provisions that allow for mounded leach fields and other State-approved alternative designs where there is not a native, in-situ, 36-inch vertical separation between the bottom of the organic horizon and the bedrock, water table, or other restrictive layer. Refer to Appendix 1.

- Revise the Phosphorus Control Ordinance to clarify that the limit of a project area does not apply to a given land use but to a demarcated limit of disturbance, such that all disturbance within that area is required to meet the erosion and sedimentation controls and other phosphorus controls under a plan required by the Phosphorus Control Ordinance.

- Require timber harvest and agricultural activities to meet the same requirements as other land uses under the Phosphorus Control Ordinance. Currently, timber management and harvesting must be conducted in accordance with a forest management plan prepared and supervised by a registered forester, while agriculture must be conducted in accordance with a soil and water conservation plan approved by the ACSWCD, making these uses effectively exempt from City oversight. Removing the exemption and requiring timber and agriculture to meet the same erosion control standards under the Phosphorus Control Ordinance would ensure that water quality protection is a central feature of any timber harvesting or agricultural activities in the Lake Auburn watershed.

- Develop a clear set of standards for farm management that will be consistently applied to farms in the watershed for the purpose of controlling erosion and limiting the delivery of excess phosphorus from the farm practices to Lake Auburn. One approach is to set a concrete limit on the amount of agricultural activities that are phosphorus-intensive (e.g., commercial raising of livestock, fertilized row crops, manure spreading). It is important to note that water quality is predicted to be much worse across all future scenarios if agricultural land use does not decline as predicted.

- Adjust the agricultural buffer strip requirement in the Lake Auburn Watershed Overlay District Ordinance to improve its effectiveness. Recommended adjustments include widening the buffer to 75 or 100 feet, requiring the buffer to be vegetated, and requiring the buffer to be located downgradient of all agricultural activities, perpendicular to the direction of overland flow, in all areas of the watershed (as opposed to requiring buffers only for agricultural activities that are adjacent to surface water).

- Update the Lake Auburn Watershed Overlay District Ordinance to reflect the revised watershed boundary, reducing the existing watershed boundary by 148 acres in the Gracelawn Road area.

- Incorporate low impact development requirements for single family residential development on the 1- and 3-acre lots allowed in the Lake Auburn watershed by way of referencing the Maine Stormwater Management Design Manual, Volume 2. The use of low impact development can help to limit the impacts of stormwater runoff and associated erosion and pollutants from sites. The standards as they apply to a water supply watershed are presented below:
    - » Disturbance on an individual lot must be less than 15,000 square feet (including building, driveway, walkways, lawn area, construction access, and grading).
    - » A minimum natural vegetated buffer must be maintained downgradient of all developed areas on the lot. This buffer shall be 50 feet wide if naturally forested or 75 feet wide if maintained as a natural meadow.
    - » No more than 7,500 square feet of impervious cover is located on the property.
    - » A minimum of 40 percent of the lot area must be maintained as an undisturbed natural area. If the existing land has been disturbed by prior activities, a natural vegetated buffer and/or undisturbed natural area may be proposed through restoration and revegetation.

Section 3, Analysis of Environmental Impacts

We found that Lake Auburn water quality in the last decade had reached a tipping point, whereby nuisance algae blooms were becoming more frequent and were threatening the filtration waiver. The partial alum treatment conducted in 2019 significantly reduced the in-column total phosphorus concentration and locked in a portion of the sediment-bound phosphorus, effectively resetting the system and giving the water districts additional time to ramp up watershed protection and nutrient reduction efforts. We also found that projecting current status quo conditions into the future (i.e., the "Business As Usual" scenario) resulted in Lake Auburn once again reaching a tipping point by 2100, even with the assumption that the in-column total phosphorus concentration and sediment-bound phosphorus would be repeatedly reset by an alum treatment every 10 years (see discussion in Section 2 about this assumption for further context). Modeled predictions for the other future scenarios where the regulatory framework is adjusted to allow more development in the Auburn portion of the watershed results in greater water quality degradation and a higher risk of blooms, ultimately triggering the need for a filtration plant in the "Maximum Development Allowing Building on LAWPC Lands" scenario. The use of low impact development techniques has a small positive effect on water quality in these future scenarios but does not ameliorate the high risk of frequent algae blooms. Taken together, the future scenarios show that Auburn alone does not have the land use control tools to stave off water quality decline in Lake Auburn; sustained collaboration with the upper watershed municipalities is essential to achieve the needed phosphorus load reductions over the remainder of the 21st century.

Section 4, Analysis of Economic Impacts

We found that expanding development in the Lake Auburn watershed provided minimal overall net economic benefit when accounting for the benefits and costs of all affected stakeholders, including the City of Lewiston who would otherwise carry the additional costs of watershed protection and water treatment through the existing cost sharing agreement in order for the City of Auburn to benefit from increased property tax revenues. In other words, the increased net benefits to the City of Auburn would be mostly or entirely offset by increased net costs to AWD and LWD customers, resulting in negligible net economic benefit to the communities served by Lake Auburn. This reallocation of benefits and costs among all affected stakeholders for the future scenarios highlights important questions of equity and fairness, which were raised during the process of producing this report and conversing with key community representatives. We emphasize that the costs associated with addressing declining water quality are costs to all water users and that the risk of incurred costs that are higher than our conservative estimates is very real.

Synthesis & Discussion

In summary, our analyses determined that Lake Auburn is nearing its assimilative capacity for nutrient load (even with the partial alum treatment) and cannot handle much more additional nutrient load without diminishing water quality and its associated benefits. We found no net environmental, economic, or social benefit supporting expansion of development in the Lake Auburn watershed. Instead, we recommend that low impact development strategies are incorporated into existing zoning standards and required for all future development and redevelopment projects in the Auburn portion of the watershed. We also recommend that the other four headwater towns of Turner, Minot, Hebron, and Buckfield also incorporate low impact development requirements on future development projects. Lake Auburn cannot maintain excellent water quality in the future without the full participation of the other watershed towns. More development cannot be allowed in the Auburn portion of the watershed even with low impact development requirements implemented in Auburn. Even if reduced development through conservation or other means is achieved in the headwater towns, any additional development in Auburn has an outsized negative impact since its drainage area goes directly to the lake. It is also important to understand that a filtration plant does not allow for greater development of the watershed because the filtration plant only treats extracted drinking water for the consumer and does not treat in-lake water quality for recreation and for meeting State criteria for designated uses.

> We found no net environmental, economic, or social benefit supporting expansion of development in the Lake Auburn watershed.

Below, we present further discussion on three important topics: regulation of septic systems, environmental risk and uncertainty, and comparable water utilities.

Regulation of septic systems: The regulatory and environmental analyses examined multiple issues surrounding septic systems and their contributions of phosphorus to Lake Auburn. At first glance, there may appear to be a contradiction between 1) the recommended ordinance revision from the regulatory analysis (Section 2) that the septic design standard should be revised in such a way that will allow previously non-buildable sites to become buildable and 2) the conclusion from the environmental analysis (Section 3) that Lake Auburn will arrive at a tipping point of declining water quality by 2100 even in the absence of any pro-development changes (i.e., the "Business As Usual" scenario). Indeed, our buildout analysis determined that more than 100 additional new homes could be built in the watershed if the septic system siting requirement for 36 inches of suitable in-situ soil were revised.

To address this apparent contradiction, we argue that the septic design standard should be judged not only by its adherence to the best available science but by its simplicity, straightforwardness, and fairness. The key questions are: does the existing septic design standard accomplish its stated purpose of regulating septic systems effectively for water quality protection, or is its water quality benefit primarily in its de facto restriction of buildable areas in the watershed? Are there improvements that could be made to achieve the stated goal? With our recommended revision, we aim to have the septic design standard achieve its stated purpose of effectively regulating both new septic system construction and replacement/reconstruction of existing septic systems as they age out, so that septic systems with alternative technologies and innovative phosphorus controls can be phased in. Restrictions on developable land are better left to base and resource protection zoning than to septic design standards.

The project team also noted in conversations with multiple Lake Auburn stakeholders a concern about an unintended consequence of the requirement in the current ordinance for 36 inches of suitable in-situ soil to site a septic system. The concern is that this requirement for deep, native soils has led to the preferential siting of some septic systems on deep formations of sand and gravel aquifer, which provide some of the only suitable sites in the watershed with the requisite depth to bedrock, water table, or other restrictive layer. While our team did not conduct any field assessments, witness this condition firsthand, or review any documentation of this condition, we agree with the premise that these sand and gravel formations should not be considered suitable sites for septic systems, at least without the importation of suitable reactive soils for nutrient and pathogen processing that the recommended ordinance revisions would allow. Adopting the Maine State standards while preserving the minimum 36-inch vertical separation would alleviate the potential for this unintended consequence.

Environmental risk and uncertainty: The risk of deteriorating water quality threatening Lake Auburn's ability to remain a high quality public drinking water supply is a throughline of this entire study. In its simplest terms, risk is the probability of a negative outcome, though the severity of the negative outcome in question is usually included when evaluating that risk. A high risk of a minor inconvenience (e.g., the risk of getting caught in traffic if leaving downtown Boston by car at 5:00 PM on a business day) requires minimal forethought, while a low risk of major damage (e.g., the risk of a flood destroying private or public infrastructure from a hurricane or Nor'easter) requires extensive planning and preparation. Uncertainty is the degree to which the risk cannot be quantified, due to a number of factors, such as insufficient data about existing conditions, insufficient predictive models for the future, and inherent randomness in nature. It is difficult but possible to predict with reasonably low uncertainty the risk of an outcome that has occurred before (e.g., an algae bloom in Lake Auburn). It gets much more difficult to predict the risk of a particular outcome (e.g., a filtration waiver violation in Lake Auburn) if that outcome has never occurred before, because the data and predictive models have not been tested against that outcome in the real world. In this situation, the uncertainty surrounding such an outcome remains relatively high even with excellent data and predictive models.

This study examined Lake Auburn's risk of negative water quality outcomes now and in the future under various scenarios, though with considerable uncertainty due to a number of confounding or unknown factors. However, we can say with certainty that all additional development raises the risk of water quality degradation, whether due to phosphorus loading, pathogens from subsurface wastewater disposal, emerging contaminants such as pharmaceuticals and personal care products, etc. Even if the increased risk resulting from any individual parcel-scale decision is small, the aggregate impact of thousands of individual decisions over the coming decades is what matters.

From a risk management perspective, the entire spectrum of outcomes should at least be understood, including the least probable, most negative outcome (i.e., the worst-case scenario). The worst-case scenario would be that Lake Auburn's water quality would deteriorate past the point of useful public drinking water supply. Phosphorus enrichment to the point of having uncontrolled algae blooms every year, with cyanobacteria and associated cyanotoxins, would be the most likely condition of such a worst-case scenario. If this unlikely but highly undesirable scenario were to occur, Auburn and Lewiston would be forced to consider other alternatives that previously would not have been seriously deliberated, such as drawing upon the Androscoggin River for drinking water. The cost of this worst-case scenario was not evaluated in our economic analysis because our environmental models do not predict conditions to deteriorate to that degree under the chosen scenarios. But in managing environmental risk, this unlikely but highly undesirable outcome should be included in the overall picture of Lake Auburn's possible future.

Comparable water utilities: Comparison of Lake Auburn and LAWPC/AWD/LWD with other water sources and utilities is illustrative of their strengths, weaknesses, and projected future needs (Table 5-1). Lake Auburn's key

Table 5-1. Lake Auburn and comparable water supply lakes and ponds in Maine.

Waterbody	Water Utility	Waterbody Surface Area (acres)	Watershed Area (acres)	Communities Served	Watershed Communities	Filtration Waiver?
Lake Auburn	Auburn Water District	2,277	9,651	Auburn, Lewiston, Poland	Auburn, Turner, Minot, Hebron, Buckfield	Yes
China Lake	Kennebec Water District	3,939	16,704	Waterville, Winslow, Fairfield, Benton, Vassalboro, Maine Water Company - Oakland	Vassalboro, China, Albion	No
Sebago Lake	Portland Water District	29,992	234,000	Portland, South Portland, Westbrook, Falmouth, Cumberland, Cape Elizabeth, Gorham, Windham, Scarborough, Raymond	24 municipalities (Androscoggin, Cumberland, Oxford counties)	Yes
Floods Pond	Bangor Water	635	4,600	Bangor, Eddington, Hampden, Hermon, Orrington, Clifton, Veazie, Hampden Water District	Otis, Clifton	Yes

comparables are China Lake, which supplies the Kennebec Water District (KWD) serving Waterville and surrounding communities; Sebago Lake, supplying the Portland Water District (PWD); and Floods Pond, used by Bangor Water, an independent water utility, to serve Bangor and surrounding communities.

China Lake is nearly double the size of Lake Auburn, with a 3,939-acre lake surface and a nearly 17,000-acre watershed, but the lake divides into two basins nearly equal in size, the west basin and the east basin. The KWD has a water supply in-take located in the west basin, where the shoreline is mostly under KWD control and managed as water supply protection land. The east basin is nearly all under private ownership and has much more shoreline development. The China Lake Outlet Stream, the only outlet of the entire lake, is in the west basin at the dam in Vassalboro. Considered by itself, the west basin is very similar to Lake Auburn in terms of shoreline and watershed management - mostly forested, under public water utility control, with universal restrictions on swimming and bodily contact but with limited recreational fishing allowed. Like Lake Auburn, China Lake serves one community within the lake watershed (Vassalboro) and several communities outside its watershed (Waterville, Winslow, Fairfield, Benton, and the Maine Water Company in Oakland), while the upper watershed towns of China and Albion do not use KWD water.

The key difference between China Lake and Lake Auburn is that China Lake has experienced algae blooms nearly every summer since the 1980s. Blooms were more severe through the 1980s and 1990s, and since the early 2000s, there have been some trends of improvement, including coldwater fish species survival. Since 1993, KWD has filtered the drinking water supply using a granular activated carbon filtration system capable of producing up to 12 MGD, though current demand stands at 3 MGD. The plant was constructed in the early 1990s for a cost of roughly $25 million. According to KWD Superintendent Roger Crouse, P.E., if water quality were to decline significantly from its current stable state, such as increased algae blooms and turbidity, KWD would have to change their operations to handle the lower quality in-take water (R. Crouse, pers. comm). The carbon filters would need to be backwashed more frequently, and the additional backwash water would need to be accommodated somehow in the existing lagoons or else the lagoons would need to be expanded at significant cost. The alum dose used to pretreat the water before filtration would also need to be raised. The key takeaway is that decreased in-take water quality at a filtration plant taxes the system, raises the volume of the waste stream, and adds significant cost and complexity to the treatment process, meaning that water supply managers cannot forgo water quality protection efforts simply because a filtration system is in place.

Sebago Lake is the public drinking water supply source used by the PWD to supply Portland, South Portland, Westbrook, and surrounding Greater Portland communities - roughly one sixth of Maine's population. The lake is roughly 10 times the size of Lake Auburn, with a surface area of nearly 30,000 acres and a watershed area of 235,000 acres. Sebago is the deepest lake in New England at 316 feet at its deepest point. Like Lake Auburn, Sebago Lake qualifies for a filtration waiver owing to a history of excellent water quality. The existing disinfection plant has a production capacity of 54 MGD and currently experiences a demand of 22 MGD. With such a large water supply lake, the capacity of the plant will be exceeded long before any concern of safe yield from the lake arises.

Land use in the Sebago Lake watershed is largely composed of private forestlands. The PWD owns 2,500 acres (or about 1% of the watershed), with 800 acres of mostly shoreland designated as 'No Trespassing' and 1,700 acres of land designated as free for public access for many forms of recreation. Another 28,000 acres are owned or managed by land trusts. The water supply in-take is at the far southern extent of the lake in the Lower Bay. A 3,000-foot 'No Trespassing' zone surrounds the in-take, and no bodily contact is allowed within two miles of the in-take. Boating, fishing, snowmobiling, and ice fishing are allowed within the 2-mile limit but not within the 3,000-foot limit. Overall, the restricted area is very similar in size and structure to that of Lake Auburn (with the exception that the on-ice activities are not allowed on Lake Auburn). Taking Sebago Lake as a whole, however, the major difference with Lake Auburn is that Sebago's Lower Bay comprises a small fraction of the overall lake, the rest of which has no special swimming or boating restrictions for water supply.

Sebago Lake and its watershed are located many miles away from the service areas of the PWD. This geographical separation means that the communities served by PWD have no ability to enact land use controls on the lakeshore or in the watershed, unlike the situation in Lake Auburn where the City of Auburn can use its zoning ordinances to enact protections for the shorefront and watershed. It is likely that this lack of control over Sebago Lake's upper watershed has spurred the PWD to focus on cooperation with land trusts and private forestland owners to conserve tracts of land. As an example, PWD Environmental Services Manager Paul Hunt told the project team that the PWD is part of a partnership, Sebago Clean Waters, that seeks to raise the total amount of land conserved (and managed at least partly for water supply protection) from the current 12% of the watershed to 25% in the next 15 years (P. Hunt, pers. comm).

In all the examples considered, the authorities in charge of water supply protection emphasize the need to maintain shoreline control as much as possible, to conserve key water supply lands, and to tightly regulate recreation, regardless of current water quality.

Floods Pond in Otis, Maine has been the public water supply source for Bangor Water, the independent water district that serves Bangor and surrounding communities since 1959. At 635 acres of surface area, surrounded by a 4,600-acre watershed in Otis and neighboring Clifton, Floods Pond is less than half the size of Lake Auburn. Maximum depth is similar at 133 feet. Like Lake Auburn, Floods Pond also qualifies for a filtration waiver owing to its historically excellent water quality.

Land use in the Floods Pond watershed is largely controlled by Bangor Water, which owns or holds landowner agreements to manage 4,500 acres or more than 99% of the watershed land area. There is no public access to Floods Pond, which is home to a native population of Arctic char (Salvelinus alpinus), a coldwater fish species closely related to both salmon and lake trout that has been used by the Maine Department of Inland Fisheries and Wildlife to establish coldwater fish populations in other Maine lakes. Fishing, boating, and swimming are prohibited, as are hiking, wildlife viewing, and hunting in posted areas that include the entire shoreline.

The geography of Floods Pond as a water supply resembles China Lake more than Lake Auburn. The vast majority of Bangor Water customers are in downstream communities (Bangor, Eddington, Hampden, Hermon, and Orrington), while the protected shoreline and watershed areas are in upstream communities that do not use the water. (A small portion of Clifton is served by Bangor Water.) Bangor Water controls nearly all the Floods Pond watershed in Otis and Clifton, 4,500 acres total and more than LAWPC controls in the Lake Auburn watershed. Recreational activities are also much more restricted at Floods Pond than at Lake Auburn. Floods Pond provides a useful comparison point at the more restrictive end of the spectrum that puts the lost tax revenues and recreational opportunities at Lake Auburn in perspective.

To summarize, these comparisons with other water supply lakes demonstrate that the protections surrounding Lake Auburn do not exceed those of China Lake, Sebago Lake, or Floods Pond. The restrictions on recreational opportunities at Lake Auburn are similar to those at other drinking water supplies, including filtered and unfiltered water sources. Similarly, land use restrictions within the Lake Auburn watershed are far from the most prohibitive among the examples discussed, with only 20% of the watershed held or managed as water supply land compared to 99% of the Floods Pond watershed. In all the examples considered, the authorities in charge of water supply protection emphasize the need to maintain shoreline control as much as possible, to conserve key water supply lands, and to tightly regulate recreation, regardless of current water quality.

Holistic Recommendations

1. We recommend that the City of Auburn not seek to ease the current resource protection zoning or

consider rezoning portions of the watershed for increased density (e.g., village node-style development). Increased density and new opportunities for residential development are better suited to other areas of Auburn outside of the Lake Auburn watershed, preferably areas already served by sanitary sewer (for the benefit of nearby water resources such as the Androscoggin River). This recommendation is based on two key findings of this study that are fully elaborated in Section 3:

- Lake Auburn and its watershed are already at or near the key environmental thresholds of 10 parts per billion annual average total phosphorus and 75% forested watershed land cover; and
- The future scenario models showed that easing restrictions on further development in the Lake Auburn watershed would set the lake on a path toward deteriorating water quality, regardless of the beneficial effects of requiring low impact development techniques and without obvious management strategies to combat further declines in water quality.

2. We recommend that the Planning Board and City Council take up our recommended ordinance revisions and, if acceptable in their current form, adopt them. If not acceptable in their current form, the recommended revisions should be reworked and made more practicable but not watered down or fundamentally changed in their intent or effect. These recommended changes represent a move toward simpler, more transparent, more evenly applied regulations that are based on the best available science. These recommended revisions are fully elaborated in Section 2 and in a separate document to the City.

3. We recommend that the City of Auburn share the findings of Section 4, Analysis of Economic Impacts, with all partners and stakeholders so that the accounting of aggregate economic impacts of the existing conditions and various future scenarios are used as the basis for an open, transparent, and thoughtful public discussion of the fairness, equity, and sustainability of the current cost sharing and benefit allocations, as well as practical ways forward. This recommendation is based on the key finding that any net benefits to the City or Auburn residents and taxpayers from expanded residential development in the Lake Auburn watershed would be counterbalanced by additional costs to Lewiston and its residents and taxpayers, in the form of increased costs associated with mitigating declining water quality and decreased benefits from recreation. These findings are fully elaborated by Section 4 of this report. As a next step in this planning process, we recommend that a scenario be modeled and run through a benefit cost analysis that meets the target water quality goal for Lake Auburn, which was not possible in the future scenarios modeled in this study when considering Auburn-only changes to regulations and management approaches. Developing a scenario that meets the water quality goal may require several iterations. The scenario should likely expand the existing Lake Auburn Watershed Overlay District to the upper watershed towns, require implementation of low impact development techniques on new development watershed-wide, and account for septic design standard changes.

4. We recommend that the City of Auburn, City of Lewiston LWD, AWD, and LAWPC fully support collaborative work with local governments, land trusts, private landowners, and other potential partners in the upper Lake Auburn watershed (Turner, Minot, Hebron, and Buckfield) to control development and limit phosphorus loading. Historically, LAWPC has been an active player in fostering collaborative action between the local governments, with representation from the upper watershed towns. This recommendation is based on the key finding from this study that Auburn alone cannot accomplish sufficient phosphorus load reductions to prevent deteriorating water quality in Lake Auburn, but will require active participation from the upper watershed towns. This finding is fully elaborated in Section 3.

5. We recommend completing a comprehensive review and gap analysis of current water quality monitoring efforts carried out by both AWD and Bates College in the Lake Auburn watershed. Identify gaps based on weaknesses and assumptions for the model. From the review and gap analysis, devise a robust long-term water quality monitoring plan and annual cost estimate for Lake Auburn. We also recommend that 1) the AWD hire a full-time, dedicated data management technician for improved management, access, and analysis of collected water quality data; 2) the AWD and LWD continue collaboration with Bates College on student-assisted monitoring; and 3) LAWPC consider creating a technical science advisory board to establish or maintain key local, State, and regional partnerships that can help to provide regular review and guidance on water quality issues.

6. Given its high probability of causing a filtration waiver violation, a swimming area will likely not be feasible for Lake Auburn at any time unless State and federal authorities sign off. If a swimming area were to be re-instituted at Lake Auburn, we provide many actions that would need to take place to ensure that the area does not contribute to water quality degradation. Refer to Swimming in Section 3.

7. Allowance of only small watercraft restricted to areas away from the in-take should continue, and improved stabilization techniques at vehicle and pedestrian access points along the lake shoreline should be implemented, along with clear and effective barriers to foot and vehicle access.

8. We recommend that the LAWPC coordinate with local youth conservation groups or AmeriCorps to perform annual maintenance of trails and install best practices that limit erosion of trails, especially those sections nearest the lake. In addition, surveying how much horse manure may be found on the trails to inform a reconsideration of horseback riding near the lake is recommended, as manure can be a significant nutrient source in sufficient quantities. Finally, it is recommended that the City acquire permanent recreational trail easements to LAWPC properties with trails for guaranteed public access in the future.

9. We recommend developing a comprehensive natural resource management plan for LAWPC lands that focuses firstly on drinking water protection and secondly on wildlife habitat protection if in the interest of public water supply protection, with multiple management options offered. We also recommend developing natural resource inventories for all LAWPC lands to map critical streams (perennial and intermittent), wetlands, vernal pools, cover types, rare, threatened, and endangered species present, etc. to include in individual natural resource management plans that set management objectives and methods to achieve water resource and wildlife habitat protection for each LAWPC parcel. If timber harvesting continues in the Lake Auburn watershed on LAWPC or private lands, then we recommend a series of actions to minimize forestry impacts to water quality. Refer to Forest Management in Section 3.

10. We recommend that LAWPC work with local conservation groups and land trusts to purchase land in the watershed outside of Auburn. We also recommend that LAWPC consider putting all their properties into permanent conservation. These properties are currently protected under the LAWPC by-laws but provide no higher-level legal protection from future development if said by-laws were to be revoked.

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Photo Credit: Sun Journal

Appendix 1

Summary of Key Watershed Protection Ordinances: Phosphorus Control Ordinance and Lake Auburn Watershed Overlay District Ordinance

Phosphorus Control Ordinance	Lake Auburn Watershed Overlay District Ordinance
Ordinance Section	
Chapter 60 – Zoning, Article XIII. Environmental Performance Standards, Division 2 Phosphorus Control (formerly Section 5.7)	Chapter 60 – Zoning, Article XII. Environmental Regulations, Division 4 Lake Auburn Watershed Overlay District (formerly Section 5.3)
Area of Applicability	
All land area within the Direct Watershed of Lake Auburn. Direct Watershed is "any land area which contributes stormwater runoff by either surface or subsurface flow to Lake Auburn without such runoff first passing through an upstream lake."	The Lake Auburn Watershed District is that section of the city in which surface and subsurface waters ultimately flow or drain into Lake Auburn.
Review/Permit/Approval/Enforcement Authorities	
Planning Board: It is understood that the Planning Board is the permit issuing authority for Phosphorus Control Permits. Permits are to be processed in accordance with Article XVI (Administration and Enforcement) of the Zoning Code. However, the way in which this is actually carried out and the portions of Article XVI that apply to the Phosphorus Control Permit process are unclear, given that the Article includes individual processes for Site Plan Review, Special Exceptions, and Subdivisions, and none references the Phosphorus Control Permit. Each process has its own set of applicability standards, submittal requirements, and performance standards. Registered forester or the Auburn Water District: Timber managing and harvesting operations are effectively removed from Planning Board oversight and diverted to the oversight by a registered forester or the Auburn Water District. Androscoggin County Soil and Water Conservation District: Agricultural practices are effectively removed from Planning Board oversight and diverted to the oversight by the Androscoggin County Soil and Water Conservation District.	City Water Department: "City Water Department" holds approval authority for agricultural uses, pending a "showing that such uses will not cause groundwater contamination or contaminate or disturb the normal course of surface water." City Water District: "City Water District" holds approval authority for tree harvesting, pending presentation of a plan prepared by a qualified forester demonstrating "conformance with good watershed management practices for domestic water supplies." City Water District: "City Water District" has the right to inspect any septic system in the Lake Auburn Watershed Overlay District during construction and operation and may notify the city health officer, police chief, local plumbing inspector, or housing inspector of issues. (Note: This is different, more expansive, than the process for inspection and enforcement in the rest of the city.) City health officer, police chief, local plumbing inspector, or housing inspector: The ordinance states that the city health officer, police chief, local plumbing inspector, or housing inspector shall require abatement of such defects or malfunctions of septic systems reported to them within the Overlay. (Note: This is different, more expansive, than the process for inspection and enforcement in the rest of the city.) (Note: The city should consider clarifying the inconsistencies in the naming convention used for the Auburn Water District. This is important because the Auburn Water District is a quasi-municipal entity that is not a conventional city department, and it is also different from the Lake Auburn Watershed Planning Commission.)
Permit Required	
Phosphorus Control Permit	No permit. Zoning use, environmental, and dimensional requirements for the district.

Phosphorus Control Ordinance	Lake Auburn Watershed Overlay District Ordinance
Permit Requirements	**Allowed Uses**
Any new building or structure with more than 575 square feet of ground floor area, expansions of ground floor area by more than 30% over the area in existence on September 21, 2009 (date of adoption of ordinance). Note that this does not define the extent of area around such project that is included in the permit requirement. Any earth moving, brush and tree cutting which impacts 10,000 square feet or more whether accomplished as a single activity or as a series of activities beginning on the date of adoption of this Ordinance shall only meet the criteria contained in Section 60-1069 (Erosion and Sedimentation Controls). Road or driveway construction and reconstruction and parking area construction which affects more than 1,500 square feet of land area whether accomplished as a single activity or as a series of activities beginning on the date of adoption of this Ordinance shall only meet the criteria contained in Section 60-1069 (Erosion and Sedimentation Controls). All projects for which Special Exception, Site Plan, and Subdivision Review is required.	Agricultural uses must be approved by City Water Department. Residential dwellings: • In the Agricultural and Resource Protection district, must be on no less than a 10 acre parcel and accessory to agricultural uses. • In other districts, as provided in the underlying zoning. 50 foot untilled buffer strip must be retained between a tilled area (where agriculture is allowed by zoning) and the normal high water mark of Lake Auburn and perennial tributaries. Erosion producing activities are prohibited if likely to increase sedimentation of Lake Auburn or tributaries. (Difficult to assess without reference to standards). Tree harvesting must be done according to a plan prepared by a qualified forester and approved by the City Water District. Municipal sludge spreading and disposal, when performed in accordance with Rules of Municipal Sludge Utilization on Land (Maine DEP, September 1980). Manure spreading and disposal, when performed in accordance with Maine Guidelines for Manure and Manure Sludge Disposal on Land (Life Sciences and Agriculture Experiment Station and the Cooperative Extension Service, University of Maine at Orono, and the Maine Soil and Water Conservation Commission, July 1972). New private sewage disposal systems only: • On sites where the highest seasonal high groundwater table, bedrock, or other impervious layer is at least 36 inches below the bottom of the organic horizon. • At least 300 feet from normal high water mark of Lake Auburn or tributaries in areas with soils described as deep, loose and sandy, or gravelly, and which contain more than 70% sand (as shown on Table 9-3 of the State Plumbing Code, Part II, April 25, 1975). • At least 1,000 feet from normal high water mark of Lake Auburn or tributaries where sewage flow is likely to be in excess of 2,000 gallons/day. Replacement or reconstruction of private septic systems in existence and use on December 17, 1983 are exempt (but must still comply with current State Plumbing Code). Buildings and structures must be 75 feet inland of the Lake Auburn normal high water mark. Docks are allowed within 75 feet of the Lake Auburn normal high water mark.

Phosphorus Control Ordinance	Lake Auburn Watershed Overlay District Ordinance
Comments on Relevant Performance Standards	
This ordinance is set up to essentially require the project per-acre phosphorus controls outlined in the Maine Stormwater Management Design Manual, Volume 2. Some of the assumptions provided in the ordinance for some of the lake phosphorus calculation parameters differ from those provided by Maine DEP in Appendix C of the above referenced manual. Specifically, the city's level of protection allotted to the lake is "0.5", and is therefore 50% more restrictive than DEP's allotment of "1.0". In addition, the city assumes a smaller area that is available for development within the direct watershed of Lake Auburn, at 1,180 acres as opposed to DEP's calculation of 1,524 acres. This results in a lower per-acre phosphorus allocation (the allowable phosphorus loading for a given development project) in the Auburn Phosphorus Ordinance than in the DEP manual. Given the recent water quality and algae bloom challenges in Lake Auburn, it can reasonably be expected that DEP will consider reducing the level of protection from 1.0 to 0.5 in the state per-acre lake phosphorus calculations for Lake Auburn. The ordinance does not clearly define the limit of a project area that must be managed to meet the required phosphorus controls. A clarification of this point could strengthen the ordinance, for example, by stating that the 'permit' area or 'project' area is defined by the area of alteration or disturbance associated with the given project. Exemptions are provided for timber management or harvesting operations conducted according to a management plan prepared and supervised by a registered forester or the AWD, as well as for agricultural uses following a soil and water conservation plan approved by the Androscoggin County Soil and Water Conservation District. These exemptions turn over regulatory and enforcement controls to other agencies that are not necessarily required to follow the same phosphorus controls unless a particular landowner chooses not to develop one of the exempted management plans. The definition of buffers surrounding agricultural activities is incomplete and/or lacks specifics. Effective buffers for water quality need to be vegetated, with woody, deep-rooted vegetation to stabilize soils and slopes and prevent erosion adjacent to lake, pond, river, and stream banks. In addition, vegetated buffers are also effective at preventing erosion and sedimentation of forested, scrub-shrub, and meadow wetlands in addition to open-water wetlands.	The definition of erosion producing activities, or clarity about how to prevent an activity from producing erosion, is not provided and therefore not clear. A reference to follow the Maine Erosion and Sedimentation Control Manual may be helpful. The septic system requirements are outright restrictive of the use of any system on certain sites, rather than allowing the use of proven alterative systems to address constraints on sites if appropriate. The current State Plumbing Code governing private onsite wastewater systems allows the use of alterative systems in certain conditions, and this flexibility can be combined with a requirement for a greater minimum depth to groundwater and bedrock than is included in the State Plumbing Code to provide additional protection in the Lake Auburn watershed. The references for guidance on municipal sludge and manure application are outdated and rely solely on a landowner to follow these manuals, rather than requiring a plan of application or providing certain minimal standards for application. Presumably, a farm plan would include provisions for manure and municipal sludge; however, review and approval of such plans is left to the Soil and Water Conservation District and the Auburn Water District and is therefore outside of Planning Board or Zoning Administrator purview. Several referenced state rules and guidance documents in the ordinance language are out of date. The Maine Subsurface Wastewater Disposal Rules (CMR 10-144 Chapter 241, last amended August 3, 2015) should supersede all references to the State Plumbing Code in the ordinance text. Likewise, the Maine Department of Environmental Protection Chapter 400 rules for Solid Waste Management, specifically Chapter 418: Beneficial Use of Solid Wastes (last amended July 8, 2018) should supersede references to "Guidelines for Manure and Manure Sludge Disposal on Land" in the ordinance text.

Appendix 2

Current Septic Design Standard

Auburn Zoning Ordinance Section 60-952(f)(1): Subsurface absorption areas shall not be permitted on sites on which the highest seasonal groundwater table, bedrock or other impervious layer is less than 36 inches below the bottom of the organic horizon. Not less than 24 inches of suitable soil shall be present below the bottom of the subsurface absorption area. The bottom of such subsurface absorption area shall not be less than 12 inches below the bottom of the organic horizon measured from the lowest point on the subsurface absorption area.

The Implication: Local standards within the Lake Auburn Watershed Overlay District limit development on a significant portion of the watershed by effectively prohibiting the use of innovative and alternative septic system and leach field designs to meet the 'depth to constraining layer' requirement. These innovative and alternative designs are otherwise allowed by the State and can achieve comparable or better nutrient removal than a traditional system and leach field.

Recommended Septic Design Standard

The Recommendation: Maintain a requirement for a minimum depth of 36 inches above the constraining layer (groundwater or bedrock), while allowing the use of State-approved alternative septic system and leach field designs that meet statewide standards.

This can be achieved by referencing the Maine Subsurface Wastewater Treatment Rules (10-144 CMR 241), with the exception that the required depth to the constraining layer would be at least 36 inches (specified by updating Table 4-F, Minimum Permitting Requirements and Minimum Design Requirements). Because the State rules already provide for the use of such alternative designs such as mounded leach fields and drip distribution systems, as well as other proprietary systems, these would be allowed in the Lake Auburn watershed as well.

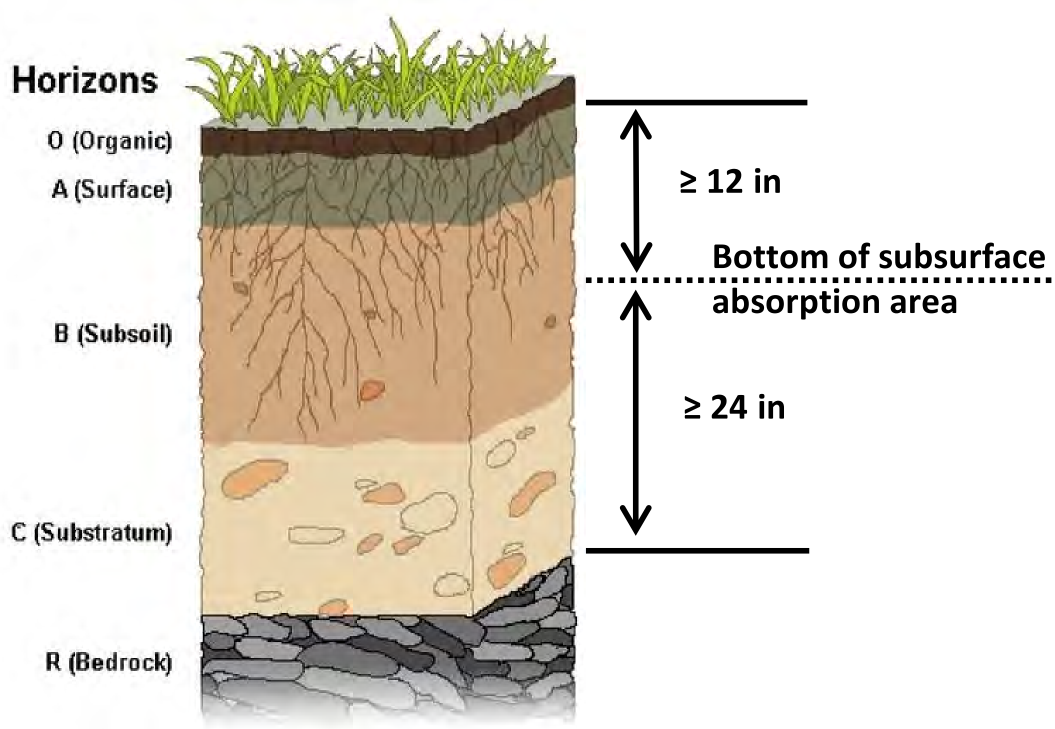
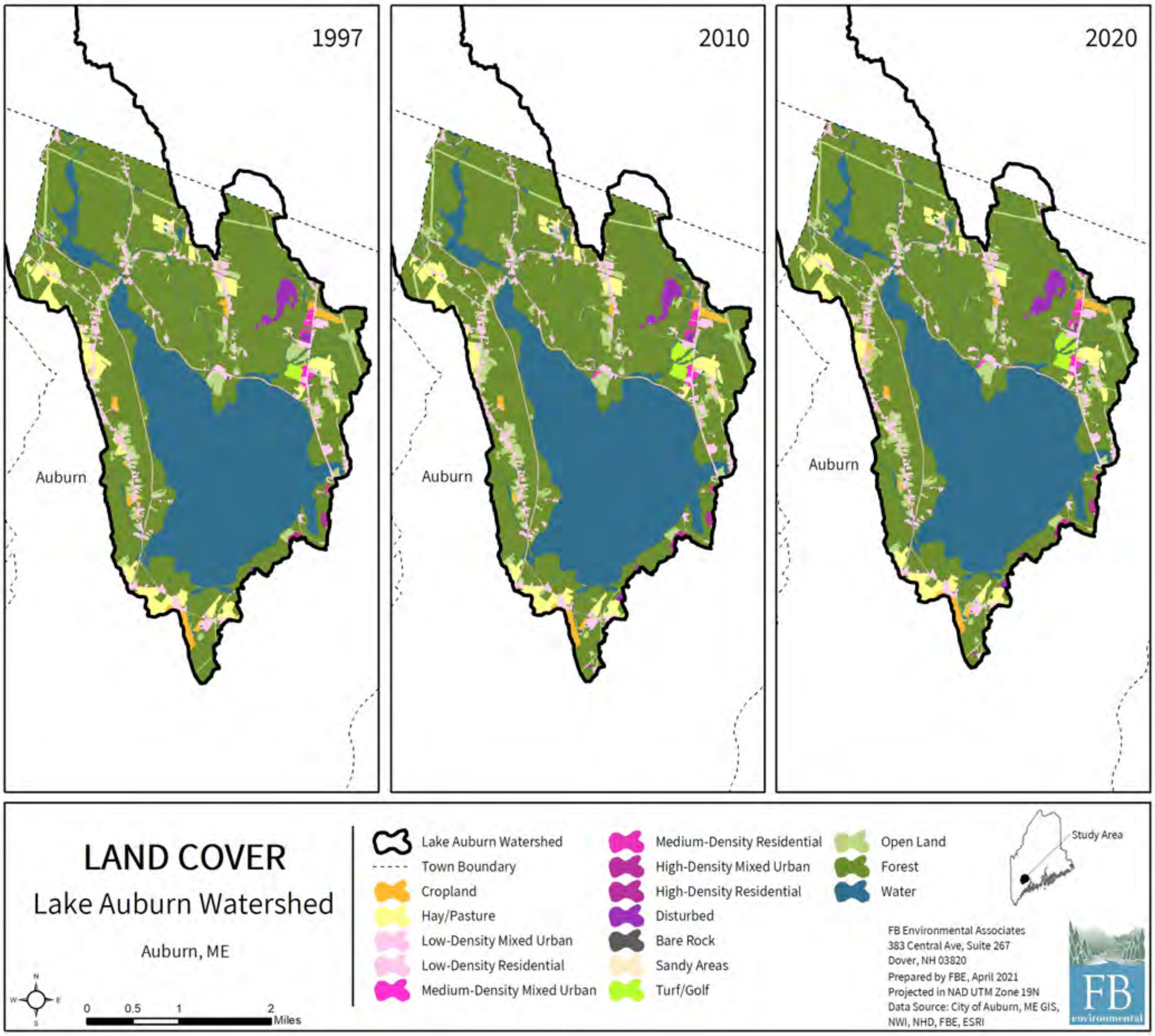
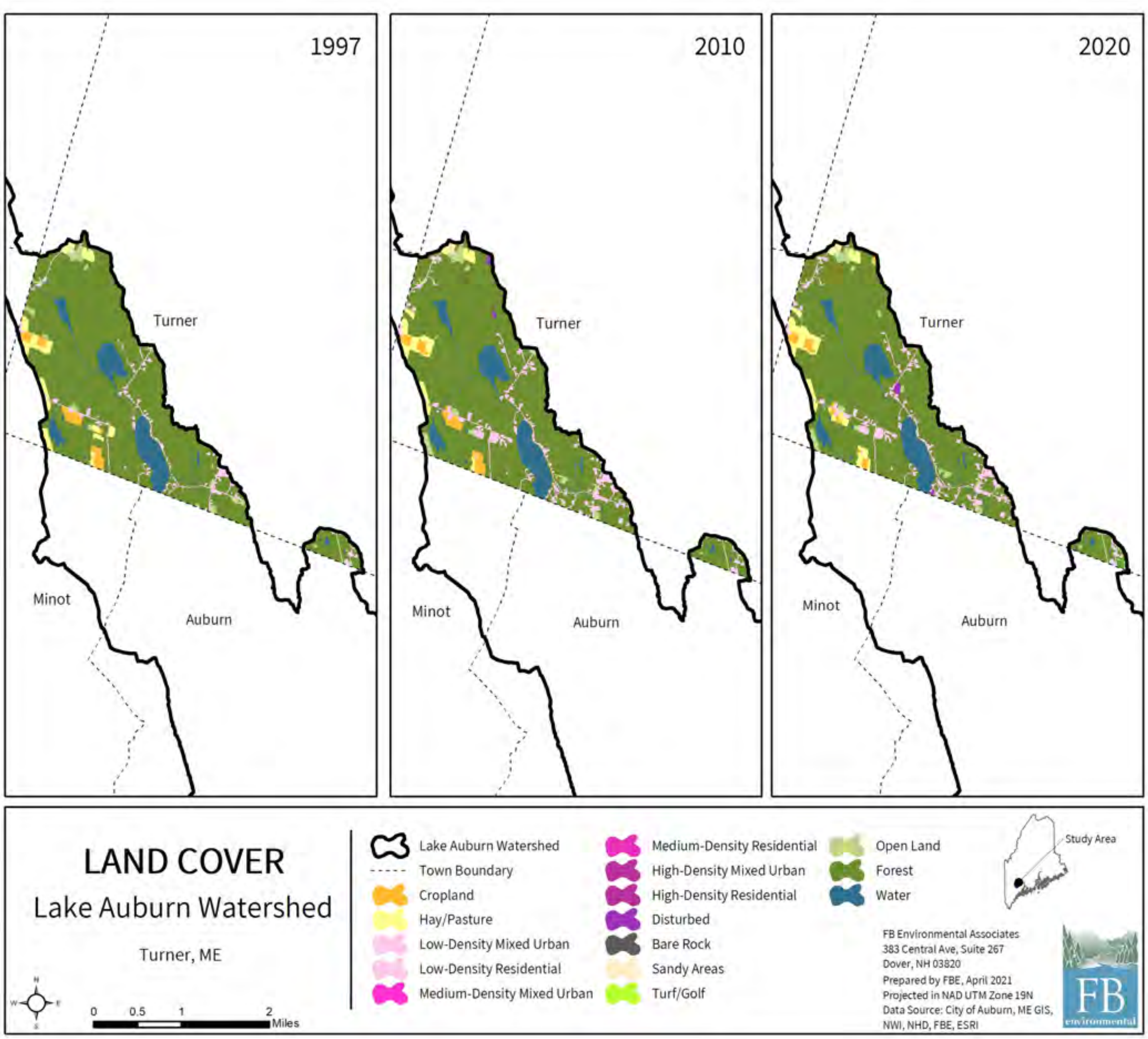


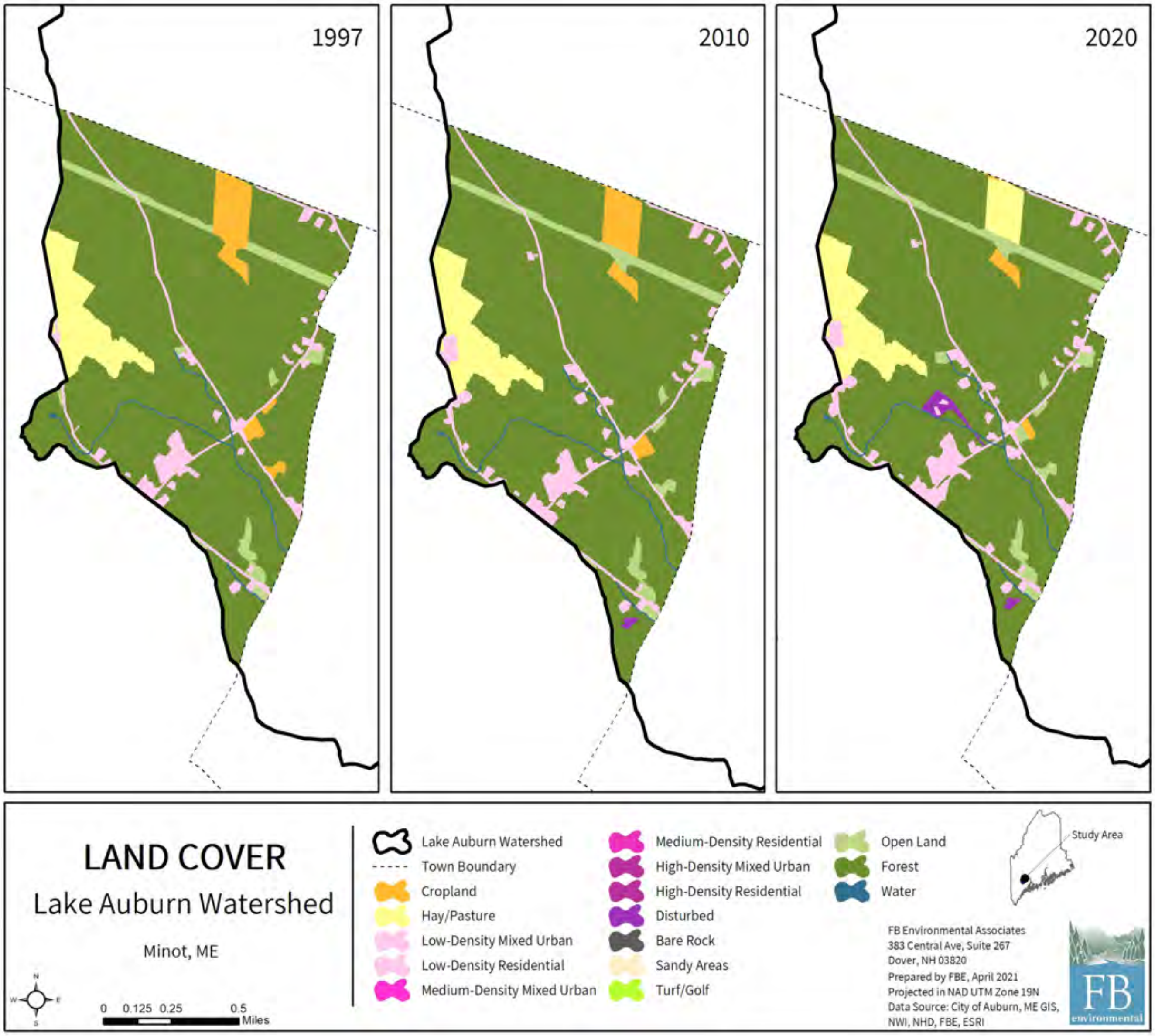
Image Credit: File:SOIL PROFILE.png by Hridith Sudev Nambiar at English Wikipedia.

Appendix 3

Land Use Change Maps By Town




1997
2010
2020
Turner
Minot
Auburn
LAND COVER
Lake Auburn Watershed
Turner, ME
0 0.5 1 2 Miles
Lake Auburn Watershed
Town Boundary
Cropland
Hay/Pasture
Low-Density Mixed Urban
Low-Density Residential
Medium-Density Mixed Urban
Medium-Density Residential
High-Density Mixed Urban
High-Density Residential
Disturbed
Bare Rock
Sandy Areas
Turf/Golf
Open Land
Forest
Water
Study Area
FB Environmental Associates
383 Central Ave, Suite 267
Dover, NH 03820
Prepared by FBE, April 2021
Projected in NAD UTM Zone 19N
Data Source: City of Auburn, ME GIS, NWI, NHD, FBE, ESRI


1997
2010
2020
LAND COVER
Lake Auburn Watershed
Minot, ME
0 0.125 0.25 0.5 Miles
Lake Auburn Watershed
Town Boundary
Cropland
Hay/Pasture
Low-Density Mixed Urban
Low-Density Residential
Medium-Density Mixed Urban
Medium-Density Residential
High-Density Mixed Urban
High-Density Residential
Disturbed
Bare Rock
Sandy Areas
Turf/Golf
Open Land
Forest
Water
Study Area
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383 Central Ave, Suite 267
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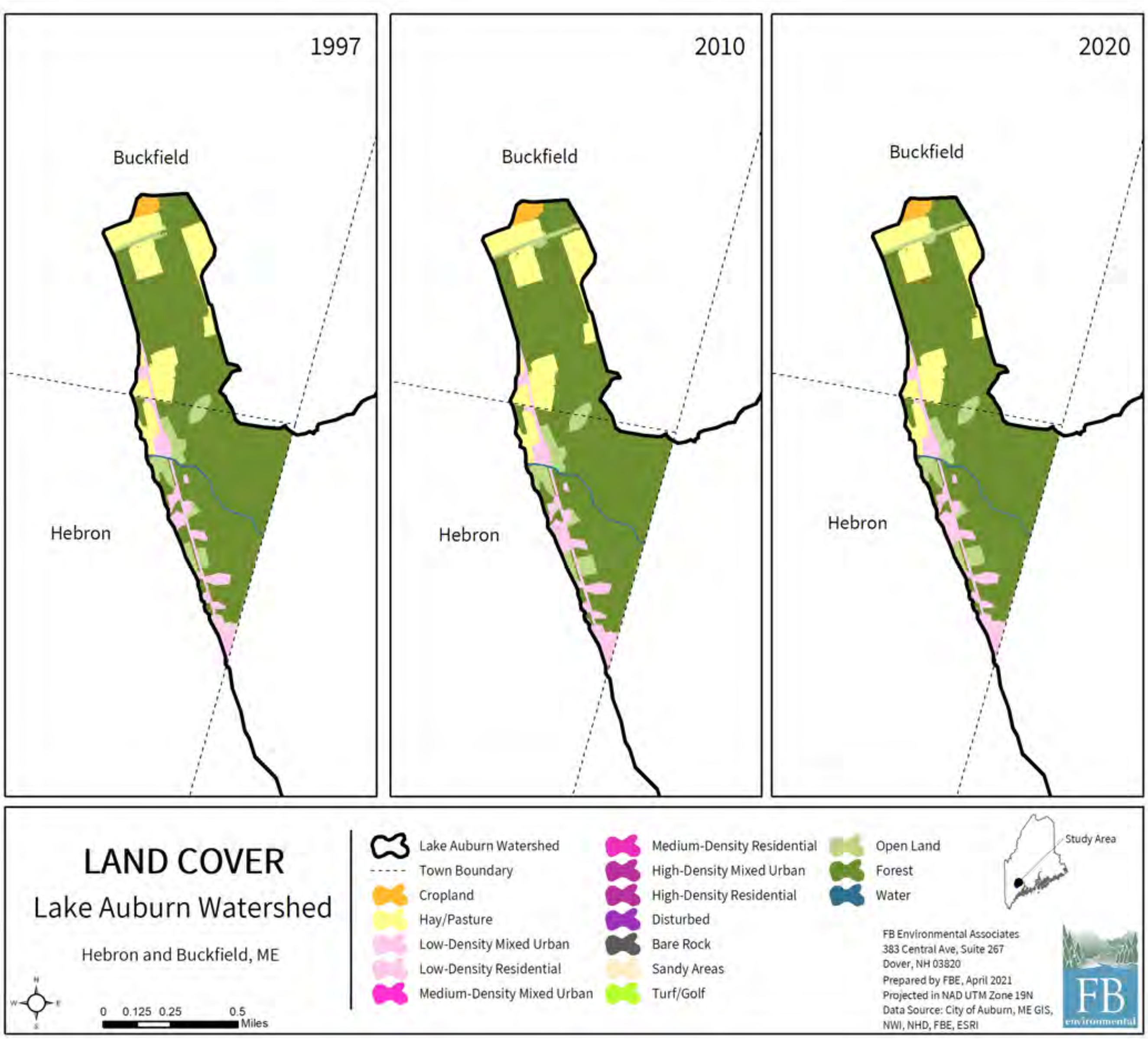
1997
2010
2020
Buckfield
Hebron
LAND COVER
Lake Auburn Watershed
Hebron and Buckfield, ME
0 0.125 0.25 0.5 Miles
Lake Auburn Watershed
Town Boundary
Cropland
Hay/Pasture
Low-Density Mixed Urban
Low-Density Residential
Medium-Density Mixed Urban
Medium-Density Residential
High-Density Mixed Urban
High-Density Residential
Disturbed
Bare Rock
Sandy Areas
Turf/Golf
Open Land
Forest
Water
Study Area
FB Environmental Associates
383 Central Ave, Suite 267
Dover, NH 03820
Prepared by FBE, April 2021
Projected in NAD UTM Zone 19N
Data Source: City of Auburn, ME GIS, NWI, NHD, FBE, ESRI

Appendix 4

Supplemental Buildout Analysis Results

Table A4-1: Buildout analysis results for all scenarios by town and zone.

Zone	Baseline		Business As Usual			Max Development Not Allowing Building on LAWPC Lands			Max Development Allowing Building on LAWPC Lands		
	No. Existing Bldgs	Total Area (acres)*	No. Proj. Bldgs	Total No. Bldgs	Buildable Area (Acres)	No. Proj. Bldgs	Total No. Bldgs	Buildable Area (Acres)	No. Proj. Bldgs	Total No. Bldgs	Buildable Area (Acres)
Auburn											
Agriculture and Resource Protection	77	4,474	74	151	928	101	178	1,471	188	265	2,631
General Business	2	40	0	2	0	44	46	20	49	51	20
Low Density Country Residential	47	276	16	63	56	24	71	106	29	76	139
Neighborhood Business	0	73	0	0	0	130	130	39	183	183	53
Rural Residential	218	815	143	361	292	279	497	557	311	529	597
Suburban Residential	75	366	6	81	5	9	84	9	17	92	15
Standard Shoreland Zone (state guidelines)	0	0	0	0	0	0	0	0	183	183	221
Buckfield											
General Development	2	155	106	108	154	106	108	154	106	108	154
Hebron											
General Development	13	175	17	30	83	17	30	83	17	30	83
Minot											
Rural District	49	843	99	148	414	99	148	414	99	148	415
Turner											
Commercial	6	19	7	13	11	7	13	11	7	13	11
General Residential I	15	94	40	55	59	41	56	60	41	56	60
General Residential II	50	219	29	79	99	29	79	100	29	79	100
Rural I	66	1,252	311	377	914	311	377	914	311	377	914
Rural II	14	634	61	75	527	61	75	527	61	75	527
Resource Protection	21	266	15	36	38	15	36	38	15	36	38
Shoreland Protection	23	110	14	37	30	14	37	30	14	37	30
Total	**678**	**9,811**	**938**	**1,616**	**3,610**	**1,287**	**1,965**	**4,531**	**1,660**	**2,338**	**6,008**

*IMPORTANT NOTE: "Total Area" by zone is calculated by parcels assigned to that zone. This is important because parcels divided between two zones are assigned to be in whichever zone a larger part of the parcel is within. The "Total Area" would be different if it was calculated from the zoning shapefile than the parcel shapefile.

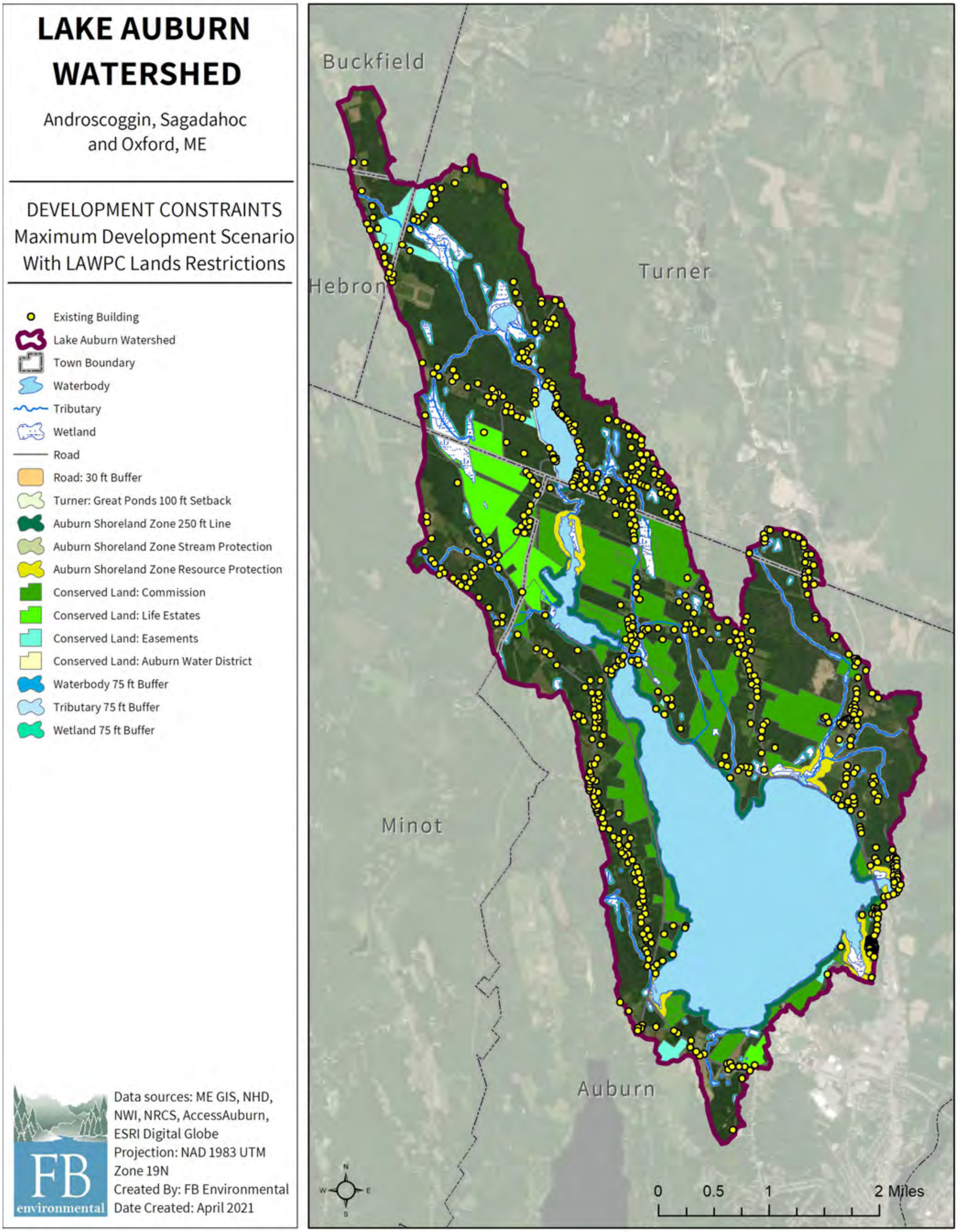

Figure A4-1. Development constraints used in the "Maximum Development Not Allowing Building on LAWPC Lands" build-out analysis for the Lake Auburn watershed.

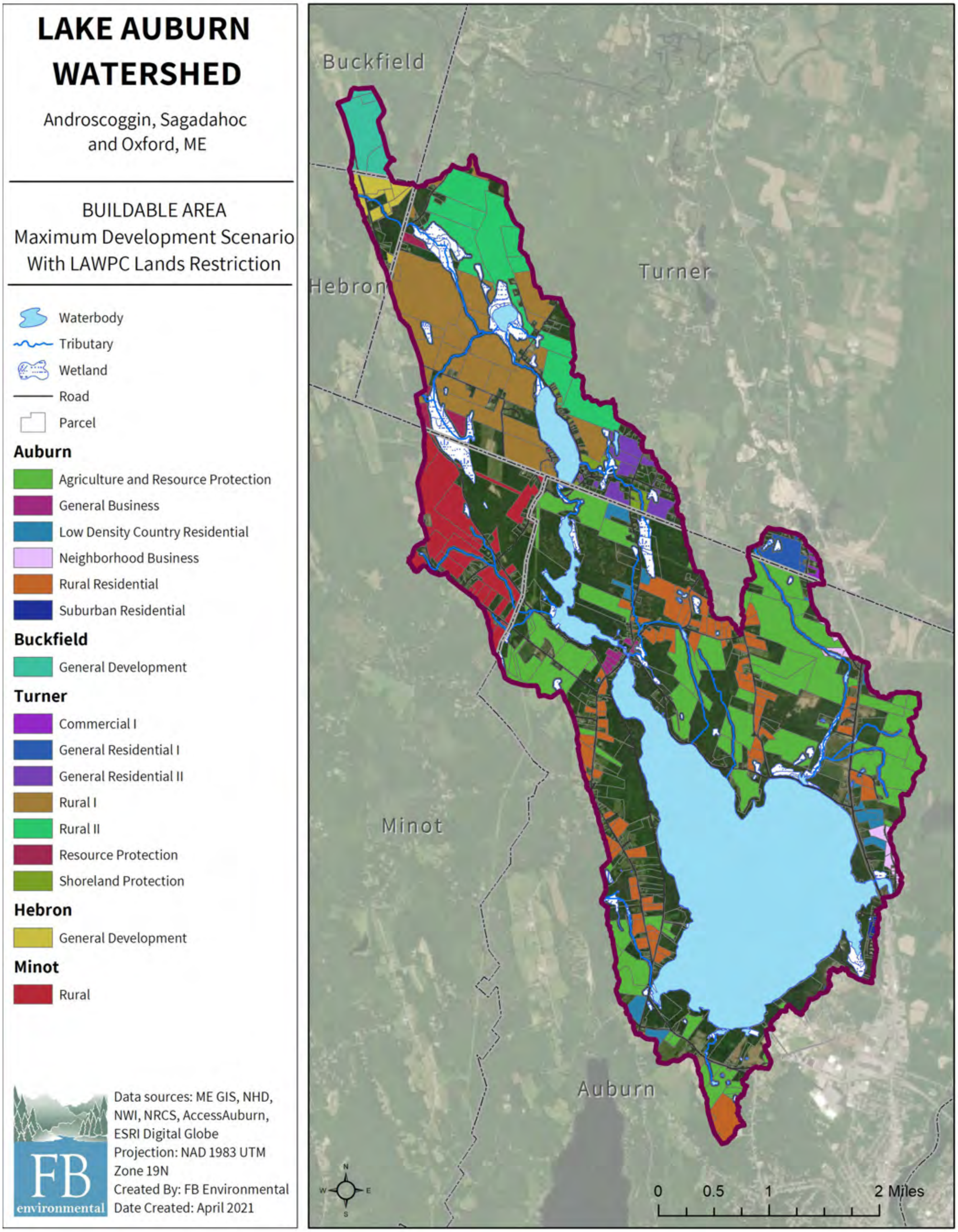

Figure A4-2. Total buildable area by zone determined from the "Maximum Development Not Allowing Building on LAWPC Lands" buildout analysis for the Lake Auburn watershed.

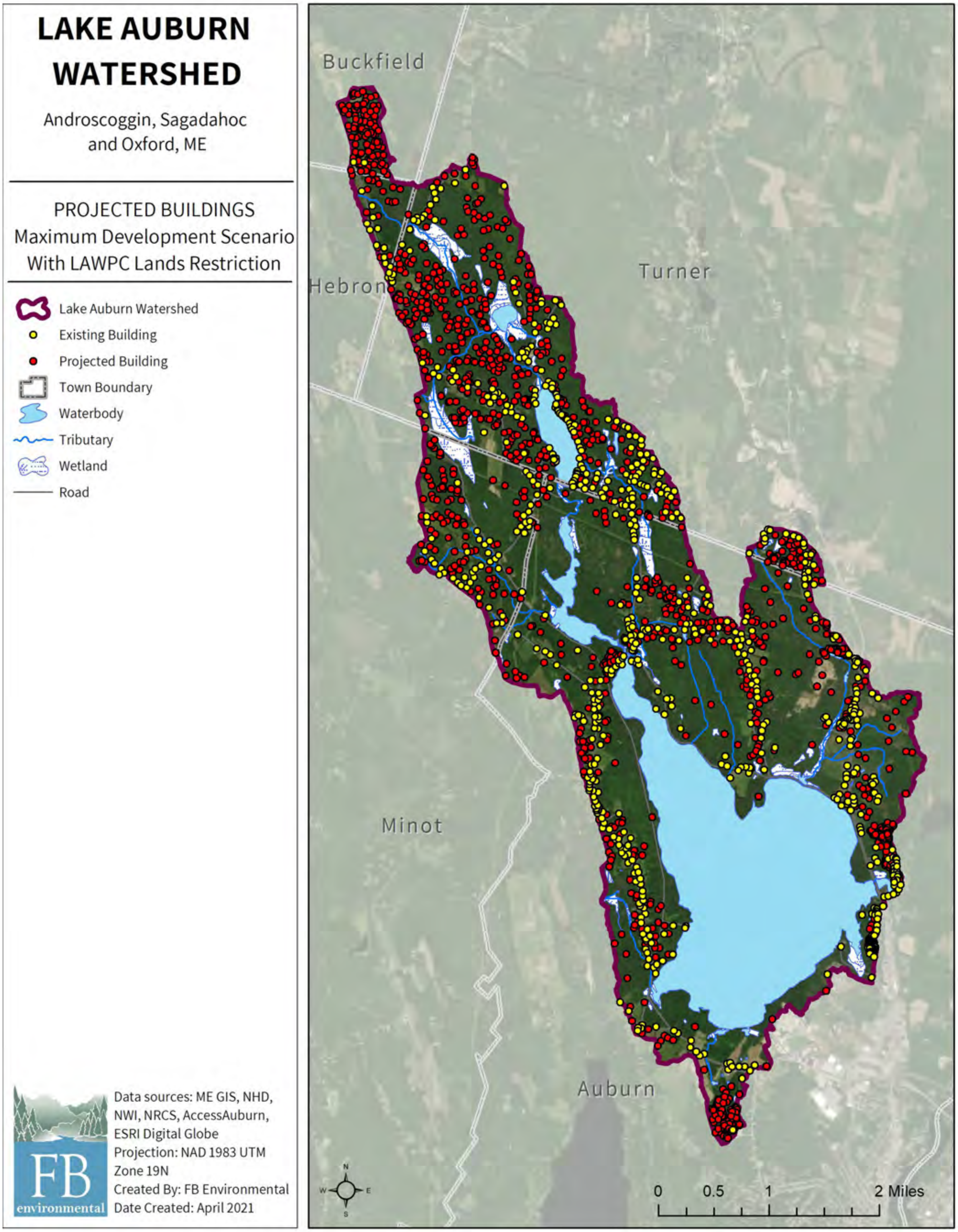

Figure A4-3. Existing (yellow) and projected (red) buildings determined from the "Maximum Development Not Allowing Building on LAWPC Lands" buildout analysis for the Lake Auburn watershed.

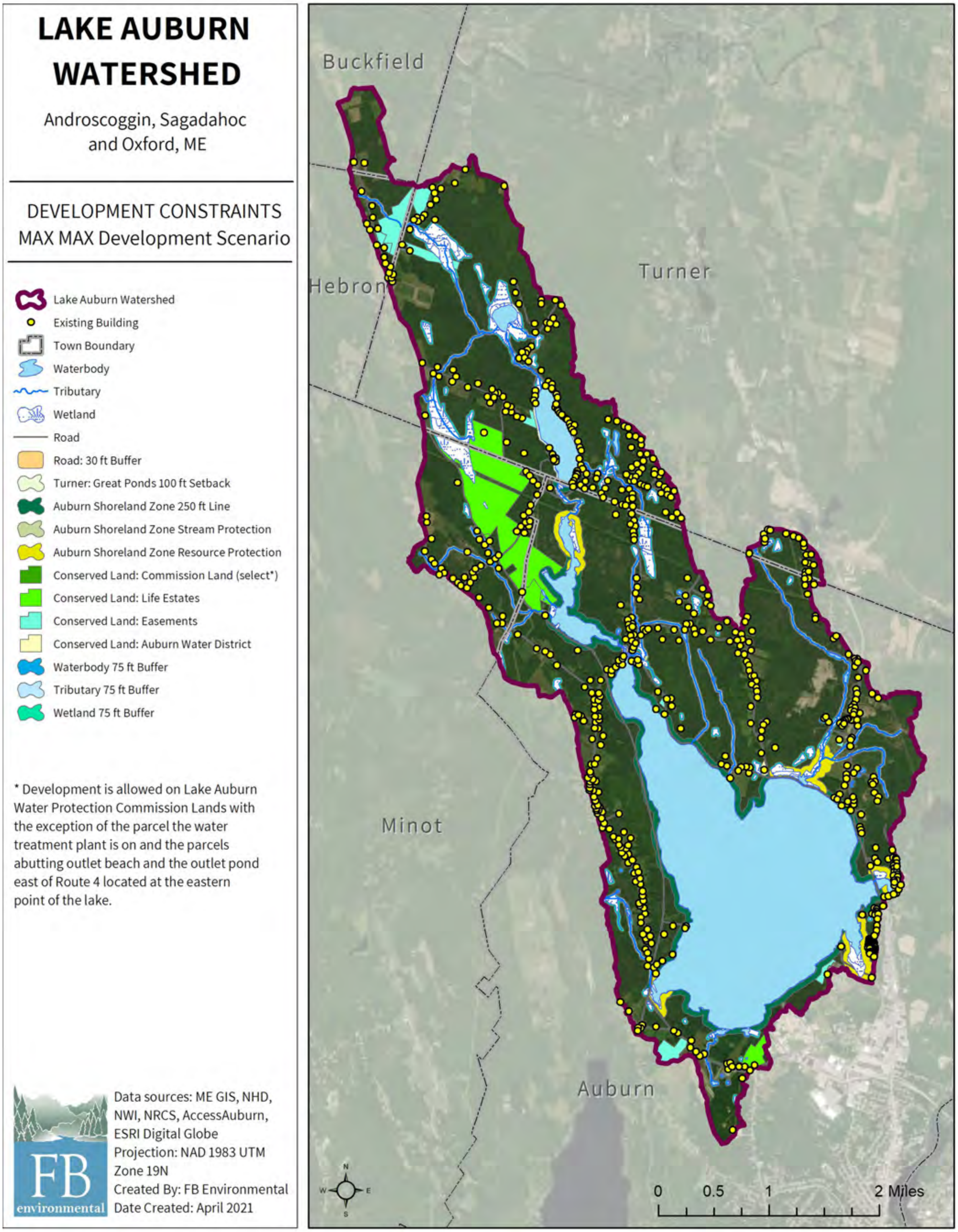

Figure A4-4. Development constraints used in the "Maximum Development Allowing Building on LAWPC Lands" buildout analysis for the Lake Auburn watershed.

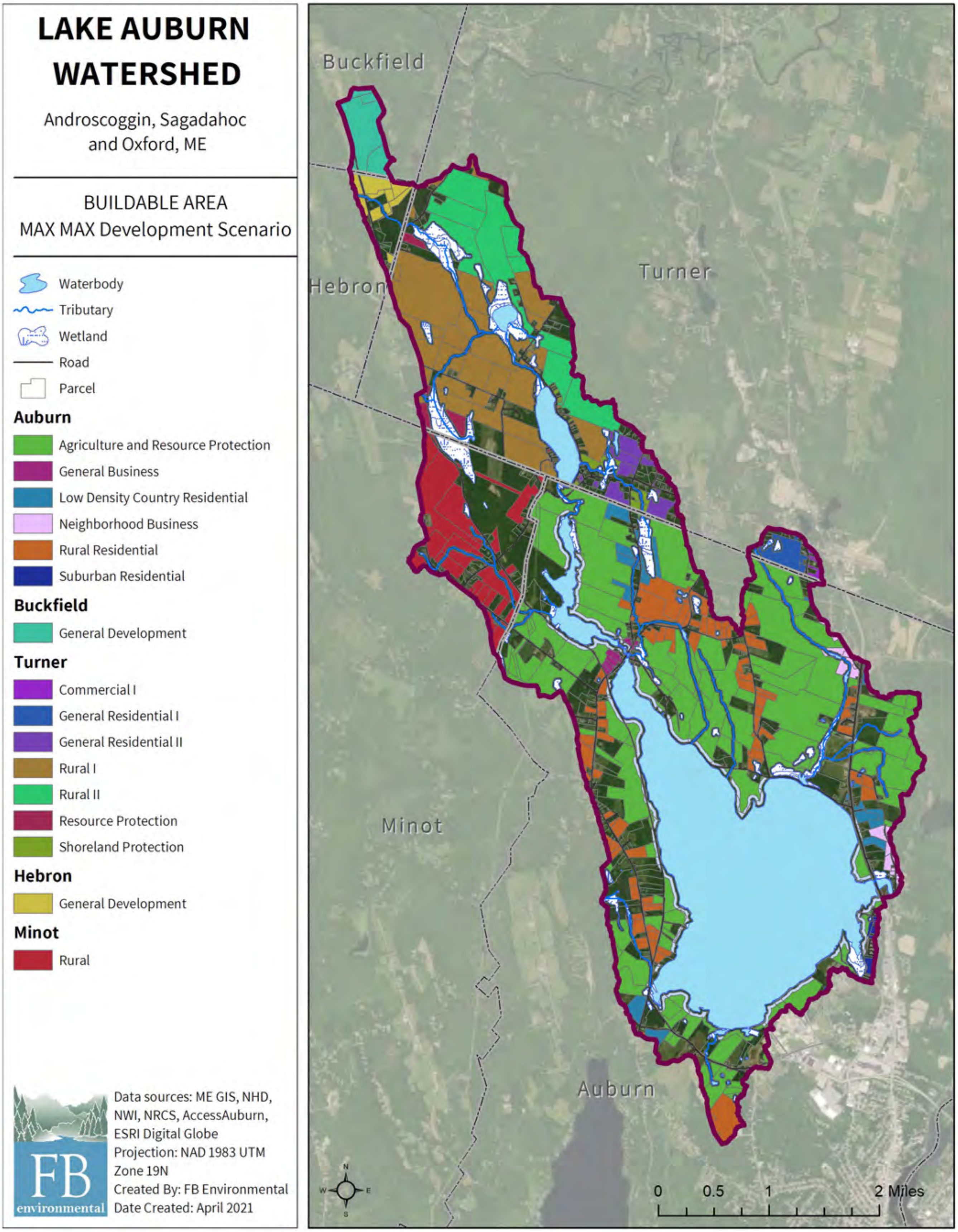

Figure A4-5. Total buildable area by zone determined from the "Maximum Development Allowing Building on LAWPC Lands" buildout analysis for the Lake Auburn watershed.

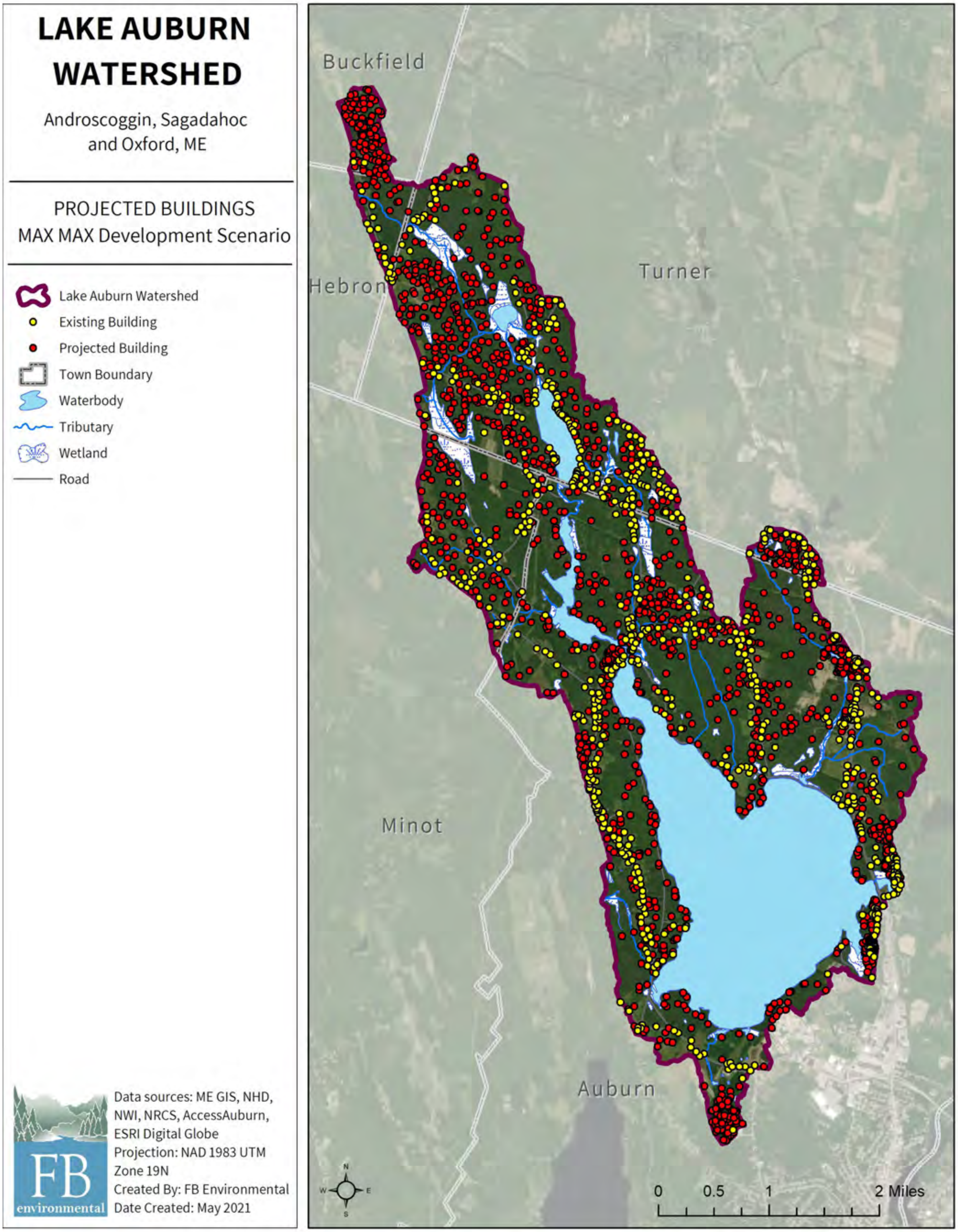

Figure A4-6. Existing (yellow) and projected (red) buildings determined from the "Maximum Development Allowing Building on LAWPC Lands" buildout analysis for the Lake Auburn watershed.