Sebago Lake Watershed, Maine Climate Change Adaptation Plan



Manomet Center for Conservation Sciences Eric Walberg, AICP, William VanDoren, Jackie Sartoris May 2013



Photos by Pam Wells, courtesy of the University of Maine Center for Research on Sustainable Forests

Contents

- 1 Introduction
- 1 The Landscape and History of the Sebago Lake Watershed
 - 1 History
 - **3** Today
- 5 Recent Planning Efforts
- 6 Stakeholder Process
- 7 Recent and Projected Climate Change in New England
- 10 Projected Changes in Extreme Weather and Climate
- 13 Adaptation Recommendations by Ecosystem Service Category
 - **13** Provisioning Services
 - **17** Regulating Services
 - **19** Ecosystems and Supporting Services
- 20 Local Capacity for Adaptation Planning and Implementation
- 22 Implementation Options
- 23 Endnotes

Tables

- 8 Table 1. Temperature and Precipitation Projections
- 20 Table 2. Survey Results: Local Staff Resources
- **21** Table 3. Survey Results: Local Ordinances and Urban Design

Figures

- 2 Map 1. Location of Sebago Lake Watershed
- 4 Map 2. Housing Density Change for the Sebago Lake Watershed
- 9 Map 3. Public Water Supply
- 10 Figure 1. Projected Changes in Extreme Weather and Climate
- 11 Map 4. Sebago Conserved Lands
- 12 Map 5. Conservation Priority Index
- 15 Map 6. Active River Area
- 16 Map 7. Stream Connectivity Impediments
- 18 Map 8. Overlap of Areas of High Geophysical Diversity and Water Supply Watershed

Suggested citation: Walberg, E., VanDoren, W., Sartoris, J. 2013. Climate Change Adaptation Plan for the Sebago Lakes Watershed. Manomet Center for Conservation Sciences, Plymouth, MA.





Introduction

Sebago Lake is the primary drinking water supply for the Portland, Maine metropolitan area. The undeveloped nature of the watershed and the corresponding high water quality allow the Portland Water District (PWD) to operate with a filtration waiver from the U.S. EPA, a significant cost savings for the utility and its customers. The combination of changing precipitation patterns, increasing intensity of storm events, and warming temperatures associated with climate change will present new management challenges. The watershed is a popular vacation destination and increasingly a place of residence for commuters that work in the Portland area. Continued residential and commercial development, in conjunction with climate change, will contribute to an increased threat of nonpoint source pollution and degradation of the historically high water quality of Sebago Lake and its tributaries.

The Landscape and History of the Sebago Lake Watershed

The Sebago Lake watershed stretches 50 miles from the town of Bethel in the north to Standish in the southeast, an area of 436 square miles and 24 towns (Map 1). Known as the Lakes Region, the area is noted for its small towns, numerous lakes, ponds, scenic views, fishing, traditional summer youth camps, and winter ski opportunities. The region derives much of its economy from tourism and many towns more than double in size in the summer.

The watershed includes two of Maine's physiographic regions, transitioning from the high peaks and ski resorts of the generally rural central highlands to the lower and flatter coastal lowlands that are increasingly the suburban homes for Portland commuters.¹ While human settlements vary in scale across the watershed, ecologically the watershed is fairly undifferentiated, presenting a landscape of mostly forested terrain and abundant freshwater resources, rolling down to flatter fallow farmland near Portland.

The single dominant geophysical feature of the Lakes Region is Sebago Lake, Maine's second largest at 47 acres, deepest at 307 feet, and bounded by a 105 mile shoreline.² In an analysis of aerial photography in 1990, roughly 86% of the watershed was forest or fallow fields, 2.5% in active timber operations, 9.3% in residential, agricultural, and commercial use, and 2.2% used for other purposes.³ Since then the population in the watershed has increased by 27%. Although no new land use analysis has been completed, the residential acreage is now most likely a few percentage points higher, at the cost of forested acreage.

History

The Lakes Region's post-European settlement history began with dispersed and independent homesteads and farms. Many of the region's towns still feature pockets of settlements around numerous small village centers, rather than a single town center. The region's economy was once based around sawmills and woolen mills that capitalized on the region's abundance of woods and waterways. Principal products of the 1800's included woven wool, wood products, and agriculture. The town of Bridgton was at one time the trading center of western Maine, due to its woolen mill and bustling downtown.

Canals dug in the 1830's linked the timberlands around Long Lake to Sebago Lake, and from there to the sea via the Presumpscot River. The canals were quickly supplanted by railways and trolleys in 1875, which greatly shortened the time to get from Portland to the Lakes Region. This stimulated the development of summer camps and cottages along the lakes.

The Maine Central railway offered stops from Standish's magnificent station up the western side of Sebago Lake to Bridgton and Harrison. The public transportation heyday in the area ended as the auto became the dominant means of transportation. The democratization of automobile ownership and paving of roads made a private commute to Portland possible for an increasing area of the Lakes Region, while simultaneously making areas further from Lake town centers attractive alternatives for vacation homes and eventually year-round family homes.







Location of the Sebago Lake watershed in southern Maine



Today

Maine's reputation and economy are inextricably linked to the quality of its natural and relatively undeveloped environment. Noted for its abundant forests and fisheries since pre-colonial times, Up to 25% of Maine's economy relies upon tourists drawn to the state's intact natural resources and commitment to its environment. The Lakes Region relies heavily on the attraction of its lakes to bring in tourists and lakefront homebuyers.

The area features contrasting land use. Much of it is forested and still quite rural, and some towns have very little commerce with just a few buildings and a crossroads to boast as town centers. Many towns still have multiple villages rather than a single town center, a reflection of the trading posts and shops that served the homesteads and farms that followed European settlement. These sleepier towns contrast with those through which the major routes pass, offering relatively speedy commutes to Portland to the south and New Hampshire to the northwest. These towns have grown substantially over the past 20 years, as commuters seek the lower housing prices and remaining rural character available further from Portland (Map 2). In many towns local officials estimate that the commuter population now exceeds 90%. Most of this growth is strip mall style development along the major Routes such as 302 and 25; lot splits with single family homes along nearby secondary roads; and pricier subdivisions on private roads set back from the secondary and tertiary roads. Those towns closest to Portland have seen the most growth by far, and are home to most of the region's national "big box" stores and fast food restaurants.

The waterfronts of the region's lakes, once home to summer youth camps and small rustic Maine summer "camps" owned primarily by Maine families, have more recently transitioned to ownership by out-of-state retirees or wealthy second home owners. "No one from here can afford to own waterfront anymore," and "the property taxes got too high," were two specific comments of an oft-repeated lament by locals. Many of the former "camps" – typically uninsulated small homes intended for three-season access to swimming and boating – were modernized and greatly expanded by new owners to maximize space, privacy, and water views. The resulting increased property values have greatly increased overall waterfront property taxes, making them unaffordable for most Maine natives. But with over 60% of local taxes linked to property values when lakes have declined in water quality have reached \$36,000.⁵ Studies have shown that lakefront values are directly tied to lake water quality, and that people are willing to pay for lake protection that preserves water quality.

Waterfront development fuels many jobs in the Lakes Region, with contractors, plumbers, excavation companies, carpenters, and landscapers dependent upon continuing property development and redevelopment for employment. Because such jobs depend upon a strong economy, these workers fell on hard times with the recent economic slowdown, with the construction industry losing an estimated 3,200 workers statewide in just one year.⁶ The irony that they are building a community that they will thus find harder to afford is not lost on many in the Lakes region construction business. Town officials noted that these blue collar workers are moving further from town centers and lakes to where the land is more affordable.

Population and density: Because of its location at the northeastern end of the highly developed I-95 corridor, Maine has seen population increases in the southern parts of the state closest to Boston as well as around Maine's largest city, Portland.⁷ This spreading growth is readily visible in aerial photographs. Despite concerted attempts by state government and nonprofits to increase density in the state and make urban areas (defined as population centers greater than 2,500) more attractive, Maine's sprawl has grown. Approximately 61 percent of residents now live in rural areas, and Maine has the highest per capita road lengths in New England.⁸ This sprawling development helps account for Maine's relatively high tax burden, ranked at 23rd per capita,⁹ while per capita income ranks at 35th.¹⁰



Map 2. Housing Density Change Map for the Sebago Lake Watershed





Map showing change in seasonal, recreational, or occasional housing density from 1990 - 2010 in and around the Sebago Lake watershed. Map based on 1990 and 2010 Tiger/LINE shapefiles of census blocks using SF-1 housing unit 100% count data, and verified using data from National Historical Geographic Information System. The housing units were distributed evenly over the block area because of changes in census block lines and converted to a density surface. Town and state boundaries and road data from MaineGIS. Hydrography data from the National Hydrography Dataset. Road data from the National Highway Planning Network.



Recent Planning Efforts

State level climate change adaptation planning: In keeping with Maine's forward-thinking environmental heritage, Maine policymakers took on the challenge of reducing greenhouse gas emissions in 2003. In 2009, the University of Maine published a risk assessment for Maine detailing the projected impacts from climate change: Maine's Climate Future. The initiative engaged over 70 stakeholder organizations over a short 9-month period, and included the collaboration of every affected state agency. When Adapting People and Nature to Maine's Changing Environment was presented to Maine's Legislature in February of 2010, it outlined a series of implementation and planning needs and listed the many ways in which Maine already had much of the needed expertise to meet the challenge of climate change.

The report acknowledged that "actions to respond, adapt, and build resilience to climate change impacts and effects occur very frequently at the local level and provide local benefits.¹²" (p. 6). The plan's major recommendation was that the initiative represented just the start of the work that needed to be done in fashioning adequate responses to climate change. Some of the recommended work commenced, including a vulnerability assessment for habitat and species, and a major project to assess public health risks is underway. In addition, the State completed the new mapping of coastal areas to enable accurate assessment of risks from sea level rise.

Brookings Institute Report: Charting Maine's Future: In 2006, Maine's State Planning Office partnered with the Brookings Institute to review Maine's economic standing and propose a way to move towards greater economic prosperity. One trend of concern the report noted was the rapid conversion of Maine's rural land.¹³ Although the report does not mention climate change, it crystallized the concern that the Maine Growth Management Act was not preventing sprawling patterns of development. The report specifically linked economic outcomes with this expensive growth trend.

Casco Bay Estuary Partnership (CBEP): CBEP is a National Estuary Program Project whose area includes the Sebago Lake watershed and numerous coastal towns. CBEP is concerned with the water and environmental quality of the Bay itself, but is also focused on improving the protection of water resources that drain to the Bay. A watershed survey of Bridgton and several other towns in the region was conducted in 2010. The survey, using dozens of trained volunteers, identified areas where erosion threated water quality. Follow up activities include seeking funding under Section 319 of the Clean Water Act to remediate identified priority areas and address culverts and other blockages to freshwater flow.

CBEP also assessed impacts to the Bay due to climate change in 2010. In particular, the report focused upon the projected impacts of sea level rise to the Bay's coastal communities, which includes Maine's most populous city, Portland.

The Lake Region Greenprint: In the Lakes Region, seven Sebago watershed municipalities joined with the Loon Echo Land Trust and the Trust for Public Land (TPL) to organize the "Lake Region Greenprint" project. The Greenprint initiative was motivated by a noticeable increase in homebuilding, particularly vacation home development in the region, sparked by the large sell off of thousands of undeveloped acres held for generations by Hancock Lumber Company. The Greenprint effort aims to meet community open space, park, recreation, and conservation interests. The seven partner communities and municipalities include the towns of Bridgton, Casco, Denmark, Harrison, Naples, Raymond and Sebago. The Greenprint initiative included analytic mapping of priority conservation areas to support the following goals:



- > Protect water resources
- > Preserve plant and animal habitat
- > Preserve working farms and forests
- Protect scenic views
- Maintain small town character of village centers
- Protect and enhance existing trails
- Provide recreation

Lakes Regional Comprehensive Plan: In 2011, the Greater Portland Council of Governments received a grant from the Maine State Planning Office to create a collaborative Comprehensive Plan with seven towns in the Lakes district: Bridgton, Casco, Frye Island, Naples, Raymond, Standish, and Windham. These communities were selected because Route 302, the heavily trafficked route that links the Lakes Region to Portland, runs through them. All of these communities have also seen higher than average residential and commercial growth over the past 20 years. Although this work is not complete, a comparison of goals in existing local comprehensive plans within the seven towns is useful.

A common theme is apparent when reviewing the details of all the planning described above: a concern for balancing the future development of Maine with preserving intact natural resources and avoiding the costs of poorly planned development.

Stakeholder Process

Manomet hosted the first of two Sebago Lake watershed stakeholder workshops on June 23, 2011 to gather input on climate change concerns and adaptation priorities. Maine Inland Fisheries Wildlife Biologist Steve Walker put the Lakes region's assets into their ecological and regional context. Carrie Walia, Executive Director, Loon Echo Land Trust, presented the just-completed Greenprint conservation plan, which encompasses many of the towns of the region. Lee Dassler, Executive Director, Western Foothills Land Trust, summarized the work of the Upland Headwaters Alliance and the Crooked River Initiative. These efforts together cover the entire Lakes region, providing a map-based prioritization of the functions and properties in each community with a focus on water quality.

Maine's State Climatologist George Jacobson, PhD., summed up Earth's climate history - with graphs tracking human population, industrial development, and the precipitous upward arc of post-industrial carbon emissions. Predicted climate shifts are dismaying, with projected human population going from today's 7 to 10 billion, and carbon emissions closely tied to human population growth. George's presentation provoked numerous questions and comments, and he urged the group to consider local sustainability in light of Maine's historical national leadership role in environmental protection.

Although Ray Sirois, of engineering firm Wright-Pierce, could not make it to the workshop, Manomet's Jackie Sartoris walked the group through his presentation of impacts of greatly increased precipitation on infrastructure, ranging from overwhelmed road culverts to flooded sewage treatment plants.

Steve Walker summarized the latest thinking on developing local incentives including ordinances that can help achieve a balance for environmental priorities and future development. Manomet's John Gunn, PhD, explained how creating a private market for water quality protection could help pay landowners for maintaining land use



practices that benefit a clean water supply. He announced the start up of Manomet's "Clear Water Carbon Fund" which will fund landowners to plant trees and maintain them along crucial parts of the Sebago Lake watershed.

During lunch, participants identified stormwater management and surface water quality as priority climate change concerns (with culvert replacement identified as a specific need). The group also gave priority to the protection of contiguous habitat, listed concerns about climate impacts to forest management, and identified a strong desire for regional planning to better plan development. Working to ensure that property can be passed intact from one generation to the next was also called out as an issue in the region. In addition, several workshop participants noted the need for better information about the costs to localities of poorly planned development and the costs that can be avoided from proactive planning for climate change impacts.

A second stakeholder workshop was held on January 25, 2013 to present the results of the local government survey and discuss the results of the research into climate change vulnerability and recommended adaptation actions.

Recent and Projected Climate Change in New England

Climate has changed significantly in New England from 1900 through 1999. Average annual temperatures have increased by 0.08 degrees Celsius (C) per decade and average winter temperatures have increased by 0.12 degrees C. The rate of average temperature increase accelerated significantly from 1970 to 2000 with average annual temperatures rising by 0.25 degrees C per decade and average winter temperatures increasing by 0.70 degrees C. Driven by these changes, growing seasons have lengthened, the number of days with snow on the ground has decreased for many locations, and the timing of peak spring stream flow has shifted to earlier in the year.¹⁴

The continued increase in atmospheric greenhouse gas levels is also driving associated increases in extreme weather events. In 2008 the U.S. Climate Change Science Program found that:

- "Human-induced warming has likely caused much of the average temperature increase in North America over the past 50 years and in turn causing changes in temperature extremes.
- Heavy precipitation events in North America have increased over the past 50 years in conjunction with observed increases in atmospheric water vapor.
- Increasing greenhouse gas concentrations have contributed to the increase in sea surface temperatures in the hurricane formation regions. Over the past 50 years there has been a strong statistical connection between tropical Atlantic sea surface temperatures and Atlantic hurricane activity as measured by the Power Dissipation Index."¹⁵

The change in frequency and intensity of extreme precipitation events differs regionally within North America with the most pronounced increase taking place in New England. A recent study of the period from 1948 to 2007 found significant increases in both the occurrence and intensity of extreme precipitation, with most occurring more recently.¹⁶

Future climate change projections indicate a likely acceleration of the changes that have occurred during the last 100 years. Due to significant unknowns such as future greenhouse gas emission rates, the influence of various feedback loops and the likely existence of climate tipping points, it is impossible to predict the exact timing and extent of climate change. However, over time climate modeling tools are becoming more sophisticated and for the most part different modeling approaches are yielding increasingly similar results.



A 2006 study downscaled output from several global climate models and produced results specific to New England for three different possible future emission scenarios (B1, A2 and A1F1 scenarios developed by the IPCC).¹⁷ Nine atmosphere-ocean general circulation models were utilized to create the downscaled projects. The B1 scenario assumes a stabilizing of atmospheric CO_2 levels at or above 550 ppm by year 2100. The A2 scenario assumes atmospheric CO_2 levels of 830 ppm by 2100 and the A1FI scenario assumes CO_2 levels of 970 ppm by 2100. Results for the B1 and A1FI scenarios for two of the modeled variables, temperature and precipitation are shown in the following table.

Table 1. Temperature and Precipitation Projections

	UNITS	2035	-2064	2070-	2099
Temperature	Degrees C	B1	A1FI	B1	A1FI
Annual		+2.1	+2.9	+2.9	+5.3
Winter		+1.1	+3.1	+1.7	+5.4
Summer		+1.6	+3.1	+2.4	+5.9
Precipitation	% change				
Annual		+5%	+8%	+7%	+14%
Winter		+6%	+16%	+12%	+30%
Summer		-1%	+3%	-1%	0%

Source: (Reference number 14, Hayhoe)

Several other variables were modeled including stream flow and drought frequency. The projected changes in stream flow are variable; low flow periods decrease slightly for all but the A1FI scenario for the period 2070-2099, in which the number of low flow days per year is projected to increase by 22 days. Drought is projected to increase for both scenarios and both time periods with the most significant increases for the A1FI scenario in the latter time period.¹⁸



Map 3. Public Water Supply Map



Map showing areas important to public drinking water supplies in and around the Sebago Lake watershed. Surface water supply watersheds show active sources of Maine public water supplies; some arbitrary truncation may occur upstream of intakes. Well models depict bedrock source water protection areas and sand/gravel aquifer areas with 200-2500 day travel times for Maine, developed using ground water models to estimate contributing areas. Well buffers show circular buffers that represent source water protection areas for wells and surface water intakes that serve the public water supply in Maine. The radius of the protection area is determined based on water system type and number of customers served. Town and state boundaries from MaineGIS. Hydrologic data from the National Hydrography Dataset (1:100k). Road data from the National Highway Planning Network.





Projected Changes in Extreme Weather and Climate

As average temperature and precipitation continue to increase in North America the projections indicate related changes in extreme weather and climate. The U.S. Climate Science Program projects that:

- "Future changes in extreme temperatures will generally follow changes in average temperature: Abnormally hot days and nights and heat waves are very likely to become more frequent. Cold days and cold nights are very likely to become much less frequent. The number of days with frost is very likely to decrease."¹⁹ (See Figure 1: source 15²⁰)
- "Over most regions, precipitation is likely to be less frequent but more intense, and precipitation extremes are very likely to increase."²¹
- "It is likely that hurricane/typhoon wind speeds and core rainfall rates will increase in response to humancaused warming. Analyses of model simulations suggest that for each 1 degree C increase in tropical sea surface temperatures, hurricane surface wind speeds will increase by 1 to 8% and core rainfall rates by 6 to 18%."²²
- * "There are likely to be more frequent deep low-pressure systems (strong storms) outside the tropics, with stronger winds and more extreme wave heights".²³



Figure 1. Projected Changes in Extreme Weather and Climate

Source: (Reference number 15, Karl)



Map 4. Sebago Conserved Lands Map



Map showing conserved lands in and around the Sebago Lake watershed. Where data allows, only lands with permanent protection through ownership in fee simple or easement are shown. Conservation status from MaineGIS (2012) or NHGRANIT (2012). Town and state boundaries from MaineGIS and NHGRANIT. Hydrologic data from the National Hydrography Dataset (1:100k). Road data from the National Highway Planning Network.









Map showing the Conservation Priority Index (CPI; Zhang and Barten, 2009) in and around the Sebago Lake watershed using 2001 land use (NLCD). The CPI scores each unit of forestland for its importance in maintaining water quality based on its distance to surface water bodies, depth to water table, soil permeability, slope, and juxaposition between surface water and roads. Areas that score higher are more important for maintaining forest cover and protecting from conversion to other uses with less favorable effects on streamflow and water quality.



Forestland occurring nearer to streams, rivers, lakes, and ponds is scored higher than forestland occurring further away. This forest in riparian areas is more important at preventing sedimentation from upland areas and regulating stream microclimate. Forestland occurring on steep slopes is more important than forest on more mild slopes. Long-lived, strong tree roots help to anchor soil against erosion. Forestland on less permeable soils, or soils with a higher water table, is more important because these soils are more vulnerable to overland flow. Forest helps to slow overland flow and offers more opportunities for adsorption of pollutants and uptake of nutrients. Finally, forest between roads and waterbodies

Adaptation Recommendations by Ecosystem Service Category

Ecosystem services are simply those services such as food production and water supply that intact, healthy ecosystems supply to humans. Climate change, in conjunction with other anthropogenic stressors, will impact ecosystem service delivery. The following sections focus on three of the many ecosystem services supplied by the Sebago Lake watershed that will be impacted by climate change, provision of drinking water, flood control and maintenance of biodiversity. These services are related in that they are all supported by the undeveloped nature of the majority of the watershed.

Provisioning Services

FRESH WATER: DRINKING WATER SUPPLY

Climate Change Vulnerabilities: Sebago Lake is the primary drinking water supply for the Portland, Maine metropolitan area (Map 3). The undeveloped nature of the watershed and the corresponding high water quality allow the Portland Water District (PWD) to operate with a filtration waiver from the U.S. EPA, a significant cost savings for the utility and its customers. The combination of changing precipitation patterns, increasing intensity of storm events, and warming temperatures associated with climate change will present new management challenges. The watershed is a popular vacation destination and increasingly a place of residence for commuters that work in the Portland area. Continued residential and commercial development, in conjunction with climate change, will contribute to an increased threat of nonpoint source pollution and degradation of the historically high water quality of Sebago Lake and its tributaries.

The Sebago Lake watershed occupies 436 square miles in southern Maine, with 75 square miles of surface area in lakes, ponds or rivers. Sebago Lake itself encompasses 47 square miles.²⁴ Sebago Lake is the second largest lake and the largest single drinking water source in Maine, providing water to 15 percent of Maine's population. More than 200,000 people and many businesses in 11 communities rely upon the quality of Sebago's drinking water.

Projected climate change impacts for the Sebago Lake watershed include a trend towards more streamflow in winter and spring and a decrease in flows in the summer and fall. The high flow events in the winter will become higher and low flow events in the summer will become lower. These changes will be accompanied by an increase in the variability and occurrence of both high and low flow events.²⁵ Also of concern is the projection for warmer water temperatures. Under higher emission scenarios the combination of higher atmospheric temperatures, longer growing season and increased evaporation rates will contribute to increases in water temperature and a reduction in dissolved oxygen levels in the summer.

The projected increase in heavy precipitation and total precipitation, in conjunction with greater impervious surface cover in the watershed will lead to more nonpoint source pollution, erosion and sedimentation in the absence of best management practices.

(cont. from previous page)

again offers the best opportunity to slow overland flow and reduce sedimentation and pollution associated with roads from entering streams. Using the default CPI input scoring strategy, any 30 meter cell of forest could receive a minimum score of 5: 3 points for forest, ½ point for a deep water table, ½ point for being well drained, and 1 point for a gentle slope. More important forestland could receive 3 points for forest, 3 points for occuring within 100 feet of a pond, lake, or wetland, 3 points for occuring near a stream, 1½ points for a shallow water table, 1½ points for being poorly drained, 3 points for occurring on a steep slope, and 3 points for occuring between a road and surface water; for a total of 18 points.

CPI implemented in the Sebago Lake watershed by VanDoren (2012). Surface water and wetland data from USGS and NWS; soils data from NRCS; and elevation data from USGS. Town and state boundaries from MaineGIS. Hydrologic data from the National Hydrography Dataset (1:100k). Road data from the National Highway Planning Network, MaineGIS, and U.S. Census Bureau.





The Sebago Lake watershed is a naturally resilient system due to the fact that forested land is by far the dominant land cover. The forest cover helps to maintain high water quality by maximizing infiltration of sediment and pollutants, thereby limiting pollution of receiving waters. Maintaining these ecosystem services will be critically important in protecting water quality against the backdrop of a changing climate.

Recommended Adaptation Actions: A recent comparison of the costs associated with a green infrastructure approach to maintaining the filtration waiver, and the cost of installing filtration technology, found significant savings with the green infrastructure approach. The analysis assumes that reducing forest cover in the watershed from the current 86 percent coverage to below 80 percent would result in loss of the filtration waiver. Savings of approximately \$70 million are projected for the green infrastructure approach as compared to the installation of filtration technology.²⁶

The Sebago Lake watershed has been studied extensively and several different approaches to identifying high priority conservation lands in the watershed exist. Three of those approaches either include a water quality component or are solely focused on water quality protection. The land conservation approach taken by the PWD, the Lakes Region Greenprint, and the Conservation Priority Index each take different metrics into account and each approach offers potential benefit in maintaining the resiliency of the watershed.

The PWD land acquisition policy supports the purchase from willing sellers of land that is both within two miles of the drinking water intake and within 500 feet of the shoreline. PWD has purchased approximately 2,500 acres adjacent to the shoreline in the lower Bay of Sebago Lake through this program. This strategy has the benefit of limiting nonpoint source pollution in the immediate vicinity of the intake. Pollutants introduced close to the intake have less opportunity to be filtered or diluted prior to reaching the intake as compared to pollutants introduced upstream in the watershed. While this approach has marked benefits in protection source water quality adjacent to the intake, it does little to address the question of watershed resiliency on a broader scale. The PWD also has a land conservation policy in place for lands outside of the two mile radius that prioritizes lands on the shoreline of the Lake and immediate tributaries for protection through conservation easements. Map 4 shows all of the currently conserved lands within the watershed.

The Lake Region Greenprint takes a broad view of conservation issues for several localities in the southern portion of the watershed.²⁷ The organizers of the Greenprint collected and analyzed information on citizen preferences for protection of open space, working lands and the services that they provide. The analysis identified water quality protection as the top citizen priority. An associated mapping exercise resulted in the identification of high priority conservation lands to meet the goal of water quality protection. The GIS analysis for protection of water resources included the following attribute data:

- aquifers for drinking water,
 wetland buffers,
 - steep slopes,
- public surface water supplies,
- Department of Environmental Protection AA water quality classification,

wellhead protection areas

headwater streams,

- areas subject to flooding,
- > wetlands that function for groundwater recharge,
- > poorly drained soils.

lake, pond, river and stream buffers,

This analysis identified of a set of lands that provide multiple benefits including riparian habitat protection, flood control, and protection of both surface and groundwater quality.



Map 6. Active River Area Map



Map showing areas vulnerable to flooding and important for riverine processes in and around the Sebago Lake watershed. The Nature Conservancy (TNC) Active River Area (ARA) data (Olivero, 2009) shows areas within which important physical and ecological processes of the river or stream occur. Town and state boundaries from MaineGIS. Hydrologic data from the National Hydrography Dataset (1:100k). Road data from the National Highway Planning Network.









NON

Map showing potential impediments to stream connectivity in the Sebago Lake watershed. Stream barrier data from Alex Abbot, c/o Gulf of Maine Coastal Program. Severe and potential barriers to aquatic organisms are displayed with red and orange triangles; while those barriers either directly observed or assumed to not be affecting organisms are shown in grey. Severe barriers are defined as those structures that have an inlet that is perched or is blocked 50% or more, or that have a perched outlet. This ranking is meant to identify crossings with the most serious and fundamental structural deficiencies related to aquatic organism passage; it is not focused on one species, but does consider fish passage first, and other aquatic organisms second. Failed culverts are automatically considered severe barriers and require immediate attention. Bridges are automatically deemed adequate. MEGIS dams shows the point locations of dams, levees, and impoundments in Maine. Town and state boundaries from MaineGIS. Hydrologic data from the National Hydrography Dataset (1:100k and 1:24k). Road data from the National Highway Planning Network. A third approach to water quality protection is the conservation priority index (CPI).²⁸ The CPI is intended as a way to prioritize land protection efforts to maximize water quality benefit given limitations in the availability of funding for watershed protection. The CPI is calculated based on several factors including:

- land use,
 permeability of soils,
- > distance to streams,

>

- distance to ponds and wetlands,
- slope,
- forested buffers between roads and receiving waters.

> depth to water table,

Compared to the Greenprint, the CPI scoring gives great value to two soils attributes, permeability and depth to water table. In addition, the CPI values existing forest cover highly, an attribute that is not included in the Greenprint. The resulting analysis is specifically focused on identifying those forested lands in the watershed that, if protected, will have the greatest water quality benefit (Map 5).

All three of the approaches outlined here identify conservation areas that are important for water quality protection and will help maintain resiliency of the watershed under climate change. In addition, the latter two approaches, the Greenprint and the CPI, address green infrastructure planning at a scale that will be meaningful in minimizing the adverse impacts of climate change.

Protection and restoration of a green infrastructure network that is focused primarily on water quality protection is among the most cost effective climate change adaptation strategies. Agreement on a future land use plan for the region is a needed next step. Much analytic work has been done, but it is not incorporated in a consistent fashion by the localities in the region. Initiatives that should be linked and coordinated include the Greenprint, PWD planning and conservation measures, CPI analysis, local planning and zoning, and the work of land trusts and conservation organizations.

Regulating Services

MODERATION OF EXTREME EVENTS: FLOOD CONTROL

- Climate Change Vulnerabilities: As discussed in the previous section, climate change is projected to bring both an increase in total annual precipitation and a continued increase in heavy precipitation events. These changes, in conjunction with continued urbanization of the watershed, will increase the flood threat in the Sebago Lake watershed. The extent, character and location of new development and the extent of direct linkage between impervious surface and receiving waters will play a pivotal role in the vulnerability of the watershed to flooding.
- Recommended Adaptation Actions: At the watershed scale, coordination between localities will be needed to identify and protect a green infrastructure network that is sufficient to keep the existing flood buffering capacity of the forested landscape intact. For individual localities, development controls that require low impact development at the site and neighborhood level will be needed to minimize the impact of new impervious surface cover. Many of the communities in the Sebago Lake watershed are in the enviable position of being rural enough to have much of the needed stormwater management handled by natural systems at low cost to the citizens. Smart land use planning and implementation will result in minimizing stormwater management costs and associated tax burden.



Map 8. TNC Focus Areas of High Resiliency and Surface Water Map





Map showing the intersection of focal areas of high estimated resilience (Anderson, Clark, and Sheldon, 2012), and public drinking water surface supply watersheds in and around the Sebago Lake watershed. These areas should be the focus of conservation efforts because they are important for water supply protection and are areas of high geophysical diversity. Public drinking water surface supply watershed data, 2012, from MaineGIS. Town and state boundaries from MaineGIS. Hydrologic data from the National Hydrography Dataset (1:100k). Road data from the National Highway Planning Network.



Ecosystems and Supporting Services

ECOSYSTEM AND HABITAT PROVISION

- Climate Change Vulnerabilities: The projected high rate of climate change will stress and disrupt existing ecosystems and create opportunities for invasive species. Cold water fisheries will be threatened by rising temperatures and changing watershed hydrology.
- > Recommended Adaptation Actions:
 - Green infrastructure network: A green infrastructure network that emphasizes protection of riparian corridors and linkage of significant habitat areas is among the most effective ways to maintain high biodiversity and resiliency to climate change. Map 6 depicts riparian areas that, if protected, would provided an important component of a watershed-based green infrastructure network. Protection of riparian forest, significant habitat areas and areas of high geophysical diversity will all contribute to ecosystem and habitat resiliency.
 - Restore stream connectivity: Map 7 shows the results of an assessment of stream connectivity in the watershed and highlights severe barriers to aquatic organism passage with red triangles. Removing these impediments will enhance the resiliency of the cold water fishery under climate change by facilitating movement of fish to cooler areas under low flow conditions. The enhanced fresh water flood threat associated with climate change will stress existing infrastructure and will result in the need to replace undersized culverts and underpasses with structures that accommodate higher flow storm events. Linking the removal of barriers to fish passage to upgrading storm water infrastructure provides a cost effective approach to dealing with both problems.
 - Protect areas of high geophysical diversity: Given that much is unknown about how >> ecosystems will respond to rapid climate change, an approach that has merit is protection of areas of high geophysical diversity. Areas of geologic and topographic diversity offer a range of habitat niches and therefore are likely to support high biodiversity as species assemblages reorganize in response to climate change. The TNC Resilient Sites approach to conservation planning is focused on the identification of areas of high geophysical diversity that will provide "the full spectrum of physical arenas that create and support species diversity."²⁹ The analysis, which includes both the Mid-Atlantic and New England, involved three stages. The first was the insuring that all geophysical settings present in the region were represented, the second was selecting sites that maximized resiliency, and the third was insuring connectivity among the sites.³⁰ The resilient sites approach is intended as a complement to more traditional methods of identifying high priority conservation areas based on existing species composition.³¹ As a component of a regional green infrastructure network, areas of high geophysical diversity complement the protection of areas of important habitat under current conditions.
 - Several of the geographic areas identified in the Resilient Sites study intersect the Sebago Lake watershed. Map 8 depicts both the resilient sites and the drinking water supply watershed areas. Their areas of intersection are shown in the green hatch. Land protection efforts in these areas will have the dual benefit of providing water quality protection and limiting development in the areas of high geophysical diversity. Obviously, to have maximum benefit from a biodiversity perspective, conservation efforts within the Sebago Lake watershed will need to be coordinated with conservation efforts in the surrounding landscape.



Local Capacity for Adaptation Planning and Implementation

Manomet performed an extensive of survey of eighteen localities in the Sebago Lake watershed to gain insight on staff capability and existing planning and regulatory structure as they relate to climate change adaptation. The topics covered in the survey included questions on planning and zoning, regulatory and non-regulatory approaches to natural resource management, stormwater management, drinking water protection, transportation issues, agriculture, and infrastructure. The results for a subset of those questions appear in Tables 2 and 3.

Table 2 shows that twelve of the localities in the watershed have no planning staff. Six of the localities have a full time code enforcement officer and eleven have only a part time officer. Eight of the localities have a conservation commission. Of those localities with a conservation commission only two involve the commission in the development review process. This indicates less than ideal staffing levels for a section of the State with high development pressure.

MUNICIPALITY NAME	PLANNER ON STAFF?	CODE ENFORCEMENT OFFICER ON STAFF?	CONSERVATION COMMISSION?
Albany Tship	No	No	Yes
Baldwin	No	РТ	No
Bethel	No	РТ	Yes
Bridgton	Yes	FT	No
Casco	Contract	FT	Yes
Denmark	No	РТ	Yes
Greenwood	No	РТ	No
Harrison	No	РТ	Yes
Naples	Contract	FT	Yes
Norway	No	PT	No
Otisfield	No	FT	Yes
Raymond	Contract	FT	Yes
Sebago	No	PT	No
Standish	Yes	РТ	No
Stoneham	No	РТ	No
Sweden	No	РТ	Yes
Waterford	No	РТ	No
Windham	Yes	FT	No
	Y=3, N=12 C=3	FT=6,PT=11, N=1	Y=9, N=9

Table 2. Survey Results: Local Staff Resources



Table 3 shows the results for several questions dealing with administration of subdivisions and urban design. Only two of the localities in the watershed have a mandatory conservation subdivision ordinance and nine have a voluntary ordinance. Seven of the localities have mapped a designated growth area and eleven have not. Finally, none of the localities indicated using form-based codes as a way to control the character of future development. The ability to accommodate continued growth in the watershed while maintaining ecosystem service delivery will be dependent on maintaining a traditional New England village development pattern. Unfortunately, the majority of the localities in the watershed do not have development controls in place that will enable that future.

MUNICIPALITY NAME	MANDATORY Conservation Subdivision ordinance?	VOLUNTARY CONSERVATION SUBDIVISION ORDINANCE?	GROWTH AREA DESIGNATED ON MAP?	FORM-BASED CODES?
Albany Tship	?	Yes	Yes	?
Baldwin	No	Yes	No	No
Bethel	No	No	No	No
Bridgton	No	Yes	No	No
Casco	No	No	Yes	No
Denmark	No	No	Yes	No
Greenwood	No	?	No	No
Harrison	No	Yes	No	No
Naples	No	Yes	Yes	?
Norway	No	No	No	No
Otisfield	No	No	No	?
Raymond	No	Yes	Yes	?
Sebago	No	Yes	Yes	No
Standish	No	Yes	Yes	?
Stoneham	?	?	No	?
Sweden	Yes	Yes	No	?
Waterford	No	No	No	No
Windham	Yes	?	No	No
	Y=2, N=14, ?=2	Y=9, N=6, ?=3	Y=7, N=11	Y=0, N=11, ?=7

Table 3. Survey Results: Local Ordinances and Urban Design



Implementation Options

Land trusts in the Sebago Lake watershed have made significant progress in protecting open space for natural resource protection, recreational use and agricultural preservation. However, it is not possible for land trusts to singlehandedly address regional resiliency to climate change. Two planning approaches could be used to support climate smart land use decisions without the need buy conservation easements on all of the land that needs to be protected. The first approach is linking the local development approval process to a green infrastructure plan. One of the best examples of this approach is found in Prince George's County, Maryland. This program requires that local development projects consider the green infrastructure plan during the site design process. Modifications to lot layout and building placement may be required to avoid encroachment into the green infrastructure network. A second approach is the establishment of local or regional transfer of development rights programs (TDR). TDR programs support the establishment of a framework to allow land owners to sell development rights in conservation areas and purchase additional development rights in designated development areas. One of the best examples of a regional TDR program focused on natural resource protection is the Pinelands Development Credit Program in New Jersey. The program is an implementation mechanism for the Pinelands Comprehensive Management Plan and has resulted in conservation of thousands of acres of environmentally sensitive and priority agricultural lands. A similar program in the Sebago Lake watershed would provide a market-based approach protecting the attributes that provide a cost-effective approach to climate change adaptation.



Endnotes

- ¹ "Why Is Sebago Lake So Deep?", Maine Department of Agriculture, Conservation and Forestry. Accessed on April 22, 2013. http://www.maine.gov/doc/nrimc/mgs/explore/lakes/sites/feb99-1.htm
- ² "Why Is Sebago Lake So Deep?", http://www.maine.gov/doc/nrimc/mgs/explore/lakes/sites/feb99.htm
- ³ "Sebago Lake Facts", Portland Water District, Accessed on April 22, 2013. <u>http://www.pwd.org/environment/sebago/facts.php</u>
- ⁴ "The Economics of Lakes", accessed April 23, 2013, <u>http://www.maine.gov/dep/water/lakes/research.html</u>
- ⁵ "The Economics of Lakes", accessed April 23, 2013, <u>http://www.maine.gov/dep/water/lakes/research.html</u>
- ⁶ "Maine Trade Group Backs Stimulus", accessed April 22, 2013, <u>http://www.sunjournal.com/node/230041</u>
- ⁷ "Population Distribution and Change: 2000 to 2010", issued March 2011, http://www.census.gov/prod/cen2010/briefs/c2010br-01.pdf
- ⁸ "Growth in Urban Population Outpaces Rest of Nation, Census Bureau Reports", March 26, 2012, http://www.census.gov/newsroom/releases/archives/2010_census/cb12-50.html
- 9 <u>http://taxfoundation.org:81/sites/taxfoundation.org/files/docs/ff2012.pdf</u>
- ¹⁰ "Personal Income per capita in Current Dollars, 2007", accessed April 22, 2013, http://www.census.gov/statab/ranks/rank29.html
- ¹¹ Richard Barringer et al., *Land for Maine's Future Program: Increasing the Return on a Sound Public Investment* (New England Environmental Finance Center and Margaret Chase Smith Center for Public Policy, January 2004).
- ¹² Maine Department of Environmental Protection. People and Nature Adapting to Climate Change: Charting Maine's Course. A Report Presented to Maine's 124th Legislature. 2010. Accessed April 27, 2013, <u>http://climatechange.umaine.edu/research/publications/climate-future</u>
- ¹³ "Charting Maine's Future: An Action Plan for Promoting Sustainable Prosperity and Quality Places", accessed April 22, 2013, <u>http://www.brookings.edu/research/reports/2006/10/charting-maines-future</u>
- ¹⁴ Katharine Hayhoe et al., "Past and Future Changes in Climate and Hydrological Indicators in the U.S. Northeast," Climate Dynamics (2007), <u>http://www.northeastclimateimpacts.org/pdf/tech/hayhoe et al climate dynamics 2006.pdf</u>.
- ¹⁵ Thomas Karl et al., Weather and Climate Extremes in a Changing Climate, Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands, 2008, <u>http://purl.access.gpo.gov/GPO/LPS110676</u>.
- ¹⁶ Susan Spierre and Camron Wake, Trends in Extreme Precipitation Events for the Northeastern United States 1948-2007 (Carbon Solutions New England, 2010), <u>http://www.cleanair-coolplanet.org/cpc/documents/2010neprecip.pdf</u>.
- ¹⁷ Hayhoe et al., "Past and Future Changes in Climate and Hydrological Indicators in the U.S. Northeast."
- 18 Ibid.
- ¹⁹ Karl et al., Weather and Climate Extremes in a Changing Climate Regions of Focus.
- 20 Ibid.
- ²¹ Ibid.
- 22 Ibid
- 23 Ibid.
- ²⁴ "Sebago Lake Facts", accessed April 22, 2013, <u>http://www.pwd.org/environment/sebago/facts.php</u>
- ²⁵ Katharine Hayhoe et al., "Past and Future Changes in Climate and Hydrological Indicators in the U.S. Northeast," Climate Dynamics (2007), <u>http://www.northeastclimateimpacts.org/pdf/tech/hayhoe_et_al_climate_dynamics_2006.pdf</u>.
- ²⁶ Erin Gray et al., Green Vs. Gray Infrastructure Options for the Sebago Lake Watershed: Preliminary Analysis and Scoping Study (World Resources Institute, July 2011).
- ²⁷ The Lake Region Greenprint: A Community Partnership (Trust for Public Land, n.d.).
- ²⁸ William VanDoren, "Hydrologic and Spatial Modeling to Quantify Ecosystem Services and Guide Outreach Efforts in the Crooked River (Sebago Lake) Watershed, Maine" (University of Massachusetts Amherst, 2012).
- ²⁹ Mark Anderson, Mellissa Clark, and Arlene Sheldon, Resilient Sites for Terrestrial Conservation in the Northeast and Mid-Atlantic Region (The Nature Conservancy, January 2012).
- 30 Ibid.
- ³¹ Ibid.



125 Manomet Point Road Plymouth, MA 02360 www.manomet.org