Forest Conservation and Management to Protect Sources of Drinking Water

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Forest management and conservation: A brief history

Forests play a key role in protecting water quality and stabilizing volume within lakes, reservoirs and rivers. The importance of forest cover in maintaining water quality and volume has been recognized as far back as 1700 BC in ancient Greece (Neary 2017). Trees, forest litter and soils are particularly well suited to deliver high quality water to streams and in moderating stream hydrology. This presumes forests remain intact and are well managed.

In the United States, the impetus to improve forest management was born out of the need to control wildfires in the west, serve recreational interests in the east and meet the growing need for safe drinking water in growing cities. These priorities were framed within arguments supporting the passage of Forest Reserve Act of 1891 and the Organic Administration Act of 1897. The Forest Reserve Act gave the president authority to "set apart and reserve" forested lands, leading to the creation of today's national forests.

Early research completed through the United States Department of Agriculture's (USDA) Forest Service Office of Silvics characterized how forests, forest litter and soils influence streamflow, control floods, and affect water quality. In 1910, the U.S Forest Service (USFS) conducted the first "watershed" study, comparing two similar watersheds in Colorado (Wagon Wheel Gap Project) by denuding one of the watersheds of its forest and measuring streamflow, then comparing that streamflow against the streamflow in the "control" watershed having an intact forest. Not long after, a research project completed in northern New Hampshire (at the Hubbard Brook Experimental Forest) demonstrated the degree to which forest cutting and burning reduced stormwater infiltration, lowered base flow and caused streamflow to increase more rapidly during storms. Over the following century, forest research has been crucial to improving water quality in lakes and rivers through better forest management practices.

Looking back to when the forests roared

Forest management today can be traced back to the negative experiences associated with uncontrolled forest cover removal, wildfires and soil erosion in many areas:

- Over 100 years ago the White Mountain region of New Hampshire was "stripped of trees from what was once virgin forest, streams choked with silt from eroding hillsides . . . ." (WhiteMountainHisotry.org) Uncontrolled logging led to flooding, low stream flows and blackened slopes affecting downstream mills, tourism and a variety of other interests.
- In 1907, catastrophic flooding on the Monongahela and Ohio Rivers was traced directly to the cut-over condition of the upstream watersheds in Pennsylvania and West Virginia.
- In 1910, wildfires devastated Idaho and Montana. The flood damage from large-scale removal of northern forests and wildfires eventually led to passage of the Weeks Act, referred to by some as the "single most important law in the creation of national forests in the eastern United States" (USFS, Celebrating a Century of Conservation) The Weeks Act was preceded by 20 years of forest research, advocacy and debate leading to the federal purchase of over 20 million acres in 26 states, including the White Mountain National Forest in northern New Hampshire in 1911. National forest research centers today, including Hubbard Brook in New Hampshire, continue innovative research concerning biomass/bioenergy, climate change and watershed management and restoration within national forests (USFS, R&D Priority Areas).

Forests are essential for safe drinking water

Forested lands are the source of more than half of the surface water supplies in the United States and provide drinking water to about 212 million Americans, through public and private water systems. Treating "raw" source water to comply with federal and/or state drinking water quality standards is complex and sensitive to water quality changes.

Regulatory compliance with health-based and aesthetic standards depends largely upon the quality of the water entering a public water system's water treatment plant. Approximately 90 chemical, radiological, and microbial contaminants have water quality standards regulated under state and/or federal Safe Drinking Water Acts. Maximum Contaminant Levels (MCLs) establish the maximum permissible level of contamination allowed in drinking provided by water public water systems.

A Forest Service study estimates that for each square kilometer (KM^2) of forest land converted from forest to urban cover within the Conserve Reservoir serving Mobile Alabama, TOC concentrations at the source water intake will increase the monthly median TOC concentrations between 33 percent and 49 percent.

The vast majority of Public Water Systems (PWSs) using surface water must install sophisticated treatment systems to remove total suspended solids (TSS), parasites (Giardia), microorganisms (*Escherichia coli*, or *E.coli*) and a range of inorganic and organic compounds.

Organic material in souce water can create harmful compounds when raw water is treated with a disinfectant, such as chlorine. Natural organic matter, (NOM) from decaying plant and animal matter, reacts with disinfectants, creating hundreds of disinfection byproducts (DBPs), some of which pose serious threats to human health and have regulatory limits. DBPs including Haloacetic acids (HAAs) and Trihalomethanes (THCs) are known to be carcinogenic at elevated levels. NOM increases Total Organic Carbon (TOC) that can affect taste and odor of treated drinking water and shorten the lifespan of treatment media, increasing the need for coagulants and disinfectants.

Converting forests to urban landscapes is estimated to increase annual phosphorus loading to a lake by a factor of ten (Horne 1994). Nutrient-rich conditions in lakes and reservoirs support algal growth and are associated with Harmful Cyanobacteria Blooms (HCBs), a growing concern for water suppliers. Cyanobacteria was recently identified by the Association of State Drinking Water (ASDWA, November 2018) as one of the top three concerns for state source water protection programs. *Microcystis*, a genus of freshwater cyanobacteria, currently being considered for future regulation and listed on U.S. EPA's Contaminant Candidate List (CCL 4), can produce a class of toxins referred to as Microcystins, harmful or fatal to humans, pets and wildlife when present at high concentrations.

Without water treatment processes capable of removing cyanobacteria cells, potentially harmful toxins within the cells can enter into finished drinking water. In New Hampshire and beyond, recent cyanobacteria blooms in water supply reservoirs and lakes, that previously did not have one on record, have elevated concerns. This has created a greater focus on reducing nutrient loading from the watershed, monitoring bloom-forming conditions and improving coordination among both state and water utilities on the response to HCBs.

Retention of well managed forests reduces nutrient loading and helps to limit the need for more complex and expensive treatment. In the northeast, Lake Sebago (serving Portland, Maine) and the Catskill/Delaware reservoir system (serving New York city), both pristine sources, provide drinking water with more limited treatment. Both water systems receive Filtration Avoidance Determinations (FADs) because their surface water sources meet strict criteria for turbidity, coliform and total trihalomethane MCLs. Avoiding additional treatment saves the Portland Water District approximately $155 million dollars. U.S. EPA FADs come with conditions to implement watershed control programs that implement comparatively cost-effective land conservation investments, non-point pollution controls and forest management practices. As New York's Commissioner of the Department of Environmental Protection statement implies, high quality source water doesn't happen by accident.

> Forests cover approximately 90 percent of New York's Catskill/Delaware watershed. (New Your City Watershed Forest Management Plan, 2017)

> *"Since the City received its first filtration waiver in the early 1990s we have protected open space around our reservoirs, invested in wastewater upgrades, forged partnerships with watershed farmers, and focused considerable attention on the forests, streams and wetlands that comprise the natural infrastructure of our water supply"* (Official Website of the City of New York 2017).

While it would seem obvious, losing forest cover in water supply watersheds appears to correlate with increasing water treatment costs. (American Water Works 2016). Based on a national survey of public water systems located within forested areas, the results "imply converting 10 percent of the watershed from forest cover to developed area increases chemical treatment costs by 8.7 percent" equating to "an annual increase of over $65,000 for the typical treatment plant in this study…". For public water systems, AWWA's report adds weight to the notion that there are tangible day-to-day financial benefits from forest ecosystem services.

Forest management within Lake Massabesic's watershed

Manchester Water Works (MWW), a large public water system operated by the City of Manchester, New Hampshire, was established in 1871. Soon after, the MWW began to purchase land along the lake's shoreline, tributaries and up-gradient pond system in the watershed. Much of the property purchased during the late nineteenth century previously was being used for sheep farming, and consisted of pastureland surrounded by stone walls. MWW began to reforest grazing areas by planting tree seedlings to accelerate reforestation. This went on for decades with over one million seedlings planted between 1871 and 1935. The majority of these were Eastern White Pine (*Pinus strobus*) as seen in Figure 1. By 1935, the MWW owned nearly 6,000 acres of forested land within the 24,000-acre watershed. Not long after MWW purchased an additional 2,000 acres.

Efforts to reforest previously cleared areas and institute forest management practices have yielded a healthy and vigorous forested landscape across the watershed. Management objectives have changed over time. Initially, pine dominated forests were managed to provide maximum tree growth potential (height and girth). Forests were thinned to remove the poor quality trees in favor of the healthy crop trees to ensure the best overall forest health. Dominated by mature, well stocked, Eastern white pine timber during the second half of the last century, forested areas had very little stocking in the mid-story or understory. An overstocked ("stocking" is the degree of utilization of land by trees), mature forest is especially susceptible to major storm damage during extreme weather

> Well-managed forests are able to contribute to the protection, availability and sustainability of high quality, cost effective drinking water (*New Hampshire Forest Resource Strategies: A Component of the 2010 Forest Resources Plan*).

Figure 1. Mature white pine forest.

events, while younger forests are more resilient, something to consider in our changing climate. Today, MWW implements both an "even-aged" and "uneven-aged" forest management approach.

Even-aged forests often result from a past harvest or clearing for pasture that has re-grown, resulting in trees of approximately the same age (Figure 2). Management involves continuously removing the smaller diameter trees (less vigorous) and leaving the larger diameter trees (more vigorous) until the final harvest (clear cut). This had been a widely used forestry practice up to the early 1990s, but it has challenges arising from a closed canopy forest with a majority dominant over-story (i.e., no understory or mid-story) that can be very susceptible to wind throw and disease. These forests often lack species diversity as well as structural diversity, and harvesting often releases relatively more nutrients into the system in the short term.

To address these challenges, MWW uses an alternative approach referred to as Uneven-Aged Management. This approach is now considered a sustainable forestry approach. It involves forest harvesting operations similar to natural forest succession and disturbance(s) including harvesting trees in small areas to create openings of ¼ to 2 acres that mimic a wind/storm event and harvesting single trees to mimic natural mortality (Figure 3).

When used together Even- and Uneven-Aged Management benefit forest health and diversity, increase the number of species, and stratify age classes and vertical structure. Shade-tolerant and -intolerant species regenerating within the openings made through "group cuts/patch cuts" enhance species variety and create a young age class, while single tree harvesting enhances addition forest growth. Forest growth is accelerated due to the availability of new growing space, water and nutrients and reduction in adjacent tree competition. This approach reduces the release of nutrients into streams and to the lake. Today, 8,000 acres of high-priority water supply lands, 35 percent of the Lake Massabesic watershed, is protected by the MWW through conservation easements, yet the remaining watershed forests are highly vulnerable to development pressure.

Forest vulnerability and loss

In the northeast, much of the land cleared during the first 200 years of European settlement has reforested itself. According to the Society for the Protection of New Hampshire Forests, Maine, New Hampshire and Vermont are currently the three most heavily forested states in the country (Table 1). New Hampshire's forests cover 84 percent of the state and have largely been at this level since the 1980s. Unlike during the 19th and 20th century, forest loss in New Hampshire today is occurring through relatively small and progressive cutting to accommodate housing and commercial development, reducing the connectivity

Figure 2. Single age class forest cover.

Figure 3. Mixed age class forest cover.

Table 1. Table of Forest Loss in NH.

Year	Forest Loss Acres (NH)
2007	628,356
2011	643,769
2017	642,597

U.S. Forest Service, Durham, 2019

and quality of forests. Small and incremental forest loss attracts little public response and is a bit like the fable of a frog in a tepid pot of water that gradually comes to a boil. It didn't end well for the frog.

In 2009 the USFS published a report evaluating the risk of losing forested lands

More than 2,000 acres of forest land are cleared for development each day in the United States, and growth projections suggest that as many as 138 million acres of private forest land will be threatened by development between 2005 and 2030 (Stein and others 2005).

within water supply watersheds in the northeast and mid-west. *Water and People: Drinking water supply and forest lands in the Northeast and Midwest United States* (Barnes et al., June 2009). This study ranked watersheds across a 20-state study area according to their ability to produce clean water, the importance/reliance upon forest lands for drinking water and threat of forest conversion based primarily upon population and housing density. Out of 540 watersheds, the Merrimack River watershed in New Hampshire ranked as the fourth-most-threatened watershed.

In another *USFS report, Private Forests, Public Benefits: Forests on the Edge* (Stein et al. 2009), the Merrimack River Watershed (comprising 5,010 square miles in southern New Hampshire and Massachusetts) ranked as the most vulnerable watershed of the 15 watersheds located in the eastern U.S. in terms of the potential timber volume loss due to future increases in housing density, modeled through the year 2030. Protecting vulnerable forests contributing source water to public water systems, like Lake Massabesic and others, is going to require a more robust and coordinated effort. Locally for New Hampshire, between 2001 and 2016, US Forest Services reports 45,000 acres of forested land, an area of 70 square miles was lost within the New Hampshire portion of the Merrimack River Watershed.

Sustainable forests: The future is . . . to be determined

Sustainable forestry ensures that future generations will have forests to meet their needs and values (Penn State Extension) USFS defines sustainabilty in terms of the impacts from decisions made by natural resource managers upon the environment, society and economy, i.e., the "triple bottom line" (Elkington, 1994) Sustainable forestry balances society's demands for land and forest products with the preservation of forest health and diversity. Changes within the 2018 Farm Bill now encourage and incentivize private landowners to make sustainable forestry decisions that better protect sources of drinking water.

Strategies for Sustainable Forest Management

- Maintain a stable forest land base
- Maintain diverse forest composition
- Maintain or increase forest biodiversity
- Maintain or increase the quality and quantity of water from forest ecosystems.

Strategies for Sustainable Forest Management (USFS)

The 2018 Farm Bill dedicates $4 billion dollars over the next 10 years, increasing the financial reach of United States Department of Agriculture's (USDA) to improve forest practices within source protection areas. The law tasks USDA through Natural Resources Conservation Services to engage public water systems. Yet, land conservation within developing areas is expensive and forest management is less relevant as forests are lost to make way for other land uses.

Source water protection is largely voluntary in most states and for large geographic areas like a watershed, can be a heavy lift. Collaborative efforts among water utilities, local, state and federal partners to share expertise and resources has been an effective approach. Echoing the U.S Forest Services' *Forest-to-Faucet Partnership* (Gregory and Barten, 2008) study of population growth trends and vulnerability of drinking water supplies, protecting forests within water supply watershed will entail raising public awareness about the value of forest ecosystem services, targeting resources to support sustainable forest practices and

accelerating preservation of forested lands within the most vulnerable water supply watersheds.

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