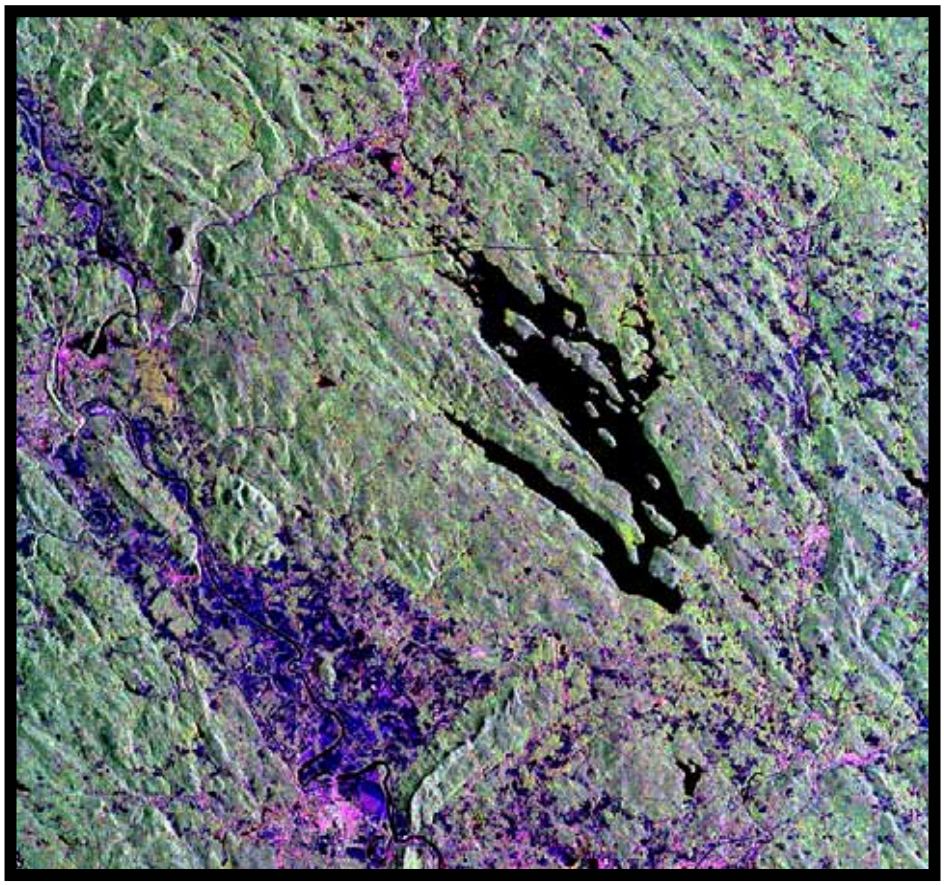
dcr
Massachusetts

QUABBIN RESERVOIR WATERSHED SYSTEM: LAND MANAGEMENT PLAN 2007-2017



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The *2007-2017 Land Management Plan for the Quabbin Reservoir Watershed System* was approved September 17, 2007 by Richard K. Sullivan, Commissioner, Department of Conservation and Recreation, and Jonathan L. Yeo, Director, DCR Division of Water Supply Protection.

Abbreviations in text:

BOF	Bureau of Forestry, a bureau in the DCR
CMR	Code of Massachusetts Regulations
CVA	Chicopee Valley Aqueduct
DCR	Department of Conservation and Recreation
DEP	Department of Environmental Protection (state)
DFG	Department of Fish and Game
DFW	Division of Fisheries and Wildlife, a division of DFG
DSPR	Division of State Parks and Recreation, a division of DCR
DWSP	Division of Water Supply Protection, a division of DCR
ELU	Ecological Land Unit
EOEEA	Executive Office of Energy and Environmental Affairs
EPA	Environmental Protection Agency (federal)
ESA	Endangered Species Act (federal)
FCPA	Forest Cutting Practices Act
FSC	Forest Stewardship Council
GIS	Geographical Information System (computer-based mapping and spatial database)
IESWTR	Interim Enhanced Surface Water Treatment Rule
IPCC	International Panel for Climate Change
MA ESA	Massachusetts Endangered Species Act
MEPA	Massachusetts Environmental Policy Act
MGL	Massachusetts General Laws
MWRA	Massachusetts Water Resources Authority
NHESP	Natural Heritage and Endangered Species Program, a DFG program
NPDES	National Pollution Discharge Elimination System
ORW	Outstanding Resource Waters
OWM	Office of Watershed Management, an office of the DCR-DWSP
PILOT	Payments in lieu of taxes
QSTAC	Quabbin Scientific and Technical Advisory Committee
QWAC	Quabbin Watershed Advisory Committee
SCS	Scientific Certification Systems
SDWA	Safe Drinking Water Act
SWTR	Surface Water Treatment Rule
WPA	Wetlands Protection Act
WsPA	Watershed Protection Act

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1 Mission, Mandates, and Planning Process

1.1 Introduction

The Department of Conservation and Recreation (DCR), Division of Water Supply Protection (DWSP), Office of Watershed Management (OWM) produces Land Management Plans for each of the watersheds under its care and control – Quabbin Reservoir, Ware River, Wachusett Reservoir, and the Sudbury Reservoir – on a rotating ten year schedule. This *2007-2017 Quabbin Land Management Plan* provides principles from the current state of the science of watershed and natural resources management, agency goals for the ten year period, and specific objectives for accomplishing these in the areas of Land Protection, Forest Management, Wildlife Management, Management and Protection of Biodiversity, and Cultural Resources Protection. The plan builds on advancements in science and management techniques, the agency's own experience over six decades of managing the watershed and its resources, and accumulated input from advisory groups and the general, concerned public. It is designed as an adaptive plan, utilizing annual reviews to build immediately on new information and changes in the science that supports management decisions, and to revise objectives, as necessary, within the ten-year time frame of the plan.

1.2 Organizational Structure

The DWSP / OWM and its predecessors have had a long tenure of providing high quality drinking water to the citizens of Massachusetts. There are a variety of laws under which DWSP must work as a drinking water supply manager. DWSP is also responsible for implementing its own regulations in its efforts to protect the drinking water source for more than a third of the citizens of the Commonwealth.

1.2.1 History

During the nineteenth century, the Boston area had obtained water mostly from Lake Cochituate in Natick, a reservoir completed in 1848 under the auspices of the Boston Water Board. Some communities were also served by the Mystic Lakes. By 1878, public health officials determined that these sources of supply would prove inadequate, so a system of seven reservoirs to supplement the Cochituate system was constructed by the Boston Water Board. These new reservoirs, created by holding back portions of the Sudbury River, were: Sudbury, Whitehall, Hopkinton, Ashland, Stearns, Brackett, and Foss (the last three referred to respectively as Framingham Reservoirs Nos. 1, 2 and 3).

Limited yield, urbanization of the watersheds, and unsatisfactory water quality led to an investigation for additional water supply of satisfactory quantity and quality. A study completed by the state health board in 1895 recommended the development of a reservoir along the South Branch of the Nashua River. The Metropolitan Water Board was created in 1895 with the planning and development of the Wachusett Reservoir. The Wachusett Dam and Reservoir were completed in 1908, harnessing the Nashua River in central Massachusetts as the new source of drinking water for metropolitan Boston.

The Metropolitan Water Board, Sewer Board, and Parks Commission were combined by the Commonwealth as the Metropolitan District Commission (MDC) in 1919. State officials realized during the 1920s that, once again, additional sources of water were needed to serve the growing needs of Eastern Massachusetts. The Quabbin Reservoir was created in the 1930s, using the Winsor Dam to impound the Swift River and flood an area formerly occupied by the four Western Massachusetts towns of Dana, Enfield, Greenwich, and Prescott. The Ware River was also identified as a source of water, which could be used from October through June when flows in the river are sufficient for diversion and there is demonstrated need. Diversions of water from the Ware River are conveyed into the Quabbin Reservoir through the Quabbin tunnel aqueduct at Shaft 11A.

The creation of the Wachusett and Quabbin Reservoirs meant that increasingly substandard source waters from many of the reservoirs in the Sudbury System could be discontinued. The Whitehall, Hopkinton,

Ashland and Lake Cochituate Reservoirs were transferred in 1947 for use as State Parks. The entire Sudbury System was officially removed from active use and classified as an emergency water supply in 1976. Today only the northern reservoirs (Sudbury and Reservoir No. 3) are classified as a reserve drinking water supply.

In 1984, the Massachusetts legislature, under Chapter 372 of the Acts of 1984, divided the former MDC Water Division into the MDC Division of Watershed Management and the Waterworks Division of the Massachusetts Water Resources Authority (MWRA). The MDC/DWM became responsible for reservoir watershed operation and management to provide a safe and sufficient supply of water to the MWRA. The MWRA became responsible for the treatment, transmission, and distribution of this water. The MDC merged with the Department of Environmental Management (DEM) in 2003 to become the Department of Conservation and Recreation (see the next section for more details).

Since water started flowing from Quabbin Reservoir in 1948, no new sources of drinking water have been required to meet the water supply needs of metropolitan Boston. Through ongoing improvements of the distribution system by the MWRA and watershed management by DCR and its predecessors, the current prognosis is that the DCR/MWRA watershed system will provide adequate supply and delivery to the MWRA member communities well into the 21st century.

1.2.2 The Department of Conservation and Recreation

The Department of Conservation and Recreation (DCR) was created in July 2003 when the legislature merged the Metropolitan District Commission (MDC) and the Department of Environmental Management (DEM). Chapter 26 of the Acts of 2003, §290 transferred the responsibilities of the former MDC Division of Watershed Management entirely to the Office of Watershed Management within the Division of Water Supply Protection. The names have changed, but the primary mission of DWSP remains constant: to provide pure water through responsible watershed management. The DCR/DWSP Office of Watershed Management, like the former MDC Division of Watershed Management, is legislatively mandated to manage and protect the drinking water supply watersheds, providing pure drinking water for distribution by the MWRA to approximately 2.2 million residents of Massachusetts.

Appropriate changes in terminology have been made throughout this document. In most cases the phrase "the Division" or the acronym DWSP is used to reference both the current and former watershed management agency within the Department of Conservation and Recreation. In some contexts, particularly in historical discussions or referencing studies and publications, the terms "Metropolitan District Commission/Division of Watershed Management," MDC and MDC/DWM remain accurate. In the context of this plan, "the Division" always refers to the Division of Water Supply Protection's Office of Watershed Management or the former Division of Watershed Management, not to any other Division in the Commonwealth. The terms "Division lands" refer to properties that are owned by the Commonwealth of Massachusetts and are under the care and control of the Division of Water Supply Protection, Office of Watershed Management.

1.2.3 Memorandum of Understanding with MWRA

There is a well established working relationship between DCR and MWRA. MWRA's ratepayers entirely fund the Office of Watershed Management's annual $30 million budget, including costs associated with land acquisition and payments in lieu of taxes. The terms of this relationship are defined in a Memorandum of Understanding (MOU) between the two agencies. The latest version of this MOU, developed soon after the creation of DCR, was signed into effect in April, 2004 (see Appendix). A key provision of the updated MOU is the requirement for an annual work plan and budget to detail all of the Office of Watershed Management's functions.

1.2.4 Water Supply Protection Trust

The legislature further enhanced the ability of the Office of Watershed Management to maintain the drinking water supply by establishing a Water Supply Protection Trust, created by Chapter 149 of the Acts of 2004, §27, and written into the general laws at MGL c. 10, §73. The trust provides a more efficient mechanism for MWRA's funding of the Office of Watershed Management. The Trust has also allowed the Office of Watershed Management to fill a wide range of critical positions that were previously frozen due to state budget constraints.

The Water Supply Protection Trust has a five person board of trustees responsible for approving the Office of Watershed Management's annual work plan and budget each spring for the following fiscal year beginning July 1. The members of the board of trustees are the Secretary of the Executive Office of Energy and Environmental Affairs, the Executive Director of the MWRA, the chairperson of the MWRA Advisory Board, a representative jointly selected by the North Worcester County Quabbin Anglers Association, Inc. and the Quabbin Fishermen's Association, Inc., and a representative from the Swift River Valley Historical Society.

1.3 Mission

The Office of Watershed Management within the Division of Water Supply Protection of the Department of Conservation and Recreation, a state agency within the Executive Office of Energy and Environmental Affairs, has been charged by Chapter 26 of the Acts of 2003, §290 with protection of the Quabbin Reservoir, Ware River, Wachusett Reservoir, and Sudbury Reservoir watersheds. The Office of Watershed Management inherits the mission derived from the MDC Division of Watershed Management's enabling legislation and subsequent amendments, found at MGL c. 92A ½ , §2. The statute directs the DWSP to:

> ...construct, maintain and operate a system of watersheds, reservoirs, water rights and rights in sources of water supply [to] supply thereby a sufficient supply of pure water to the Massachusetts Water Resources Authority, and [to] utilize and conserve said water and other natural resources to protect, preserve and enhance the environment of the Commonwealth and to assure the availability of pure water for future generations.

The body of legislation makes directives on specific management aspects of the watersheds, authorizing DWSP to:

- Have the exclusive right and control over all ponds, reservoirs, and other property within the watershed system, and [may] order all persons to keep from entering in, upon or over the waters thereof and the lands of the commonwealth or towns surrounding same.
- Make rules and regulations for the protection of the watersheds.
- Establish the Quabbin Watershed Advisory Committee, the Watershed System Advisory Committee (covering Wachusett and Sudbury watersheds), and the Ware River Watershed Advisory Committee.
- Adopt periodic watershed management plans to provide for forestry, water yield, and public access among other purposes.

Beyond its broad mandate, DWSP has additional, specific responsibilities as provided in various legislative acts. Some of the acts most currently relevant to DWSP are listed in **Table 1**.

Building on the legislatively-defined mission, DWSP's charge today is:

- To maintain and operate the source facilities (including dams) safely and efficiently.
- To preserve and improve water quality of the supply sources, through regulation, direct action, and cooperation, as needed to protect public health and to meet state and federal water quality standards.

- To fulfill the watershed protection and management requirements associated with drinking water regulations.
- To implement the specific directives of the legislature, such as providing recreation opportunities balanced with the protection of the water supply sources and promulgating and enforcing rules and regulations for DWSP lands and for protected zones.
- To involve watershed towns, residents, and the public in appropriate ways in the conduct of the DWSP's watershed management functions.

In addition, DWSP has defined water quality goals for the system:

- Primary Goals
  - To prevent waterborne disease.
  - To maintain a high quality source water.
  - To meet the source water coliform criterion.

- Secondary Goals
  - To reduce/control nutrient inputs to the reservoir.
  - To reduce risk of a chemical or hazardous material spill.
  - To control general pollutant transport into the reservoir.

Together, the mission and water quality goals provide the basis for all of DWSP's activities.

1.4 Regulatory Framework

1.4.1 DWSP Related Acts and Regulations

The Massachusetts Legislature has passed numerous laws over the past century to ensure an adequate and safe flow of drinking water to the metropolitan Boston region. These Acts range from enabling the construction of Wachusett and Quabbin Reservoirs to defining membership on advisory boards to regulating access to water supply lands and land use activities in the watershed. See **Table 1** for a comprehensive list of legislative acts relevant to DWSP. The creation of different agencies and authorities over time, as described in Section 1.2, is an important milestone in the evolution of this drinking water supply. Two acts that have had a significant impact on how DWSP protects and manages these water supply resources are the Kelly-Wetmore Act and the Watershed Protection Act.

The Kelley-Wetmore Act (Chapter 737 of the Acts of 1972) (see **Appendix II**) dictates the type of public access allowed and the rules for management on the Quabbin Reservoir and Ware River watersheds ("the district"). Sample guidance in this law includes the following:

- "The natural ecology of the district shall be maintained, and it shall be conserved in its present degree of wilderness character and shall be protected in its flora and fauna in all reasonable ways to assure the balanced wildlife habitat…"
- "No new or additional roads or ways shall be constructed…excepting as shall be required for forest management and fire control or for watershed and reservoir purposes, nor shall existing soft surface roads or ways be hard surfaced, provided, however, that existing ways may be maintained and kept passable and in repair."
- "The commissioner or his designee shall annually prepare a plan detailing forestry activities…which plan shall be open to inspection by the public."
- "Lumbering or logging operations shall be permitted within the district to the extent and for the purpose of maintaining and conserving its forests in a healthful state of natural ecological balance…"

Table 1: Legislative Acts Relevant to the DWSP Office of Watershed Management

Source	Summary
Chapter 488 of the Acts of 1895	Creates Metropolitan Water Board, with diverse duties and authorities, including construction of Wachusett Reservoir by taking waters of the Nashua River.
Chapter 168 of the Acts of 1901, §§ 1,5	Creates Metropolitan Water and Sewage Board.
Chapter 350 of the Acts of 1919, §123	Creates MDC.
Chapter 321 of the Acts of 1927	Authorizes creation of Quabbin Reservoir by taking waters of the Swift River; and diverse related activities.
Chapter 21 of the Acts of 1931, §1	Grants bird management authority.
Chapter 77 of the Acts of 1932	Authorizes removal of game fish from Wachusett for stocking purposes.
Chapter 262 of the Acts of 1932	Authorizes sewer construction.
Chapter 421 of the Acts of 1946	Permits fishing in certain parts of the Quabbin Reservoir (from the shore).
Chapter 300 of the Acts of 1947	Amends c. 421 of the Acts of 1946 to allow adoption of regulations governing fishing and water supply protection.
Chapter 737 of the Acts of 1972 (Kelly-Wetmore)	Sets forth rules for the management of Quabbin and Ware lands.
Chapter 204 of the Acts of 1975	Allows MDC administrative rights of entry similar to those of the DEP Division of Water Pollution Control.
Chapter 797 of the Acts of 1979	Requires Payment in Lieu of Taxes (PILOT Payments) to municipalities.
Chapter 372 of the Acts of 1984	Creates DWM (and MWRA), with diverse duties and authority.
Chapter 734 of the Acts of 1985	Adds to the list of organizations from which QWAC membership may be nominated.
Chapter 436 of the Acts of 1990	Amends c. 737 of the Acts of 1972 to allow hunting in accordance with a deer management program.
Chapter 36 of the Acts of 1992 (Watershed Protection Act)	Establishes land use restrictions around water features in Quabbin, Ware and Wachusett; land acquisition authority and related provisions.
Chapter 242 of the Acts of 1995, §§ 2, 3	Creates Ware River Watershed Advisory Committee.
Chapter 26 of the Acts of 2003, §290	Creates Department of Conservation and Recreation, Division of Water Supply Protection.
Chapter 149 of the Acts of 2004, §27	Creates Watershed Trust.

Source: DCR/DWSP/OWM, 2005.

The Watershed Protection Act (WsPA, Chapter 36 of the Acts of 1992) established a comprehensive scheme to regulate land use and activities within certain critical areas of the Quabbin Reservoir, Wachusett Reservoir and Ware River watersheds. Some of the strategies used by the WsPA to minimize the effects of human activities on water quality include: preserving a buffer zone along the water resources, limiting impervious surfaces, and restricting the storage and use of hazardous materials. DWSP utilizes the WsPA to avoid detrimental land uses close to water resources and guide development into more appropriate locations, densities and configurations.

The passage of the Watershed Protection Act provided the opportunity to unify various watershed protection regulations into 350 CMR 11.00. While the first eight sections of these regulations specifically relate to the WsPA, 350 CMR 11.09 provides the agency the general authority to protect the water supply from pollutants (See **Appendix II;** please note that any reference to "the Commission" in these regulations is now DCR). The WsPA also authorized a $135 million bond for land acquisition, to be spent at a rate of $8 million per year. $100 million was spent before the remaining $35 million was integrated into the 2002 Environmental Bond.

1.4.2 Other Regulatory Requirements

A variety of federal and state regulations exist that pertain to drinking water watershed protection. OWM staff diligently work to comply with these laws. See **Table 2** for a list of these laws.

The federal Safe Water Drinking Act and its Surface Water Treatment Rules are of particular concern to OWM. The Surface Water Treatment Rules (SWTR) regulations were promulgated in June 1989 to reduce the risk of waterborne disease from microbial pathogens. The SWTR provides two paths for adequate public health protection. It requires filtration for all surface drinking water supplies, unless the water supply is of very high quality and meets specific criteria to qualify for a filtration waiver. One of these criteria, which has been met by DCR, is an adequate watershed control program. The rule emphasizes the need for the watershed control program "to minimize the potential contamination by *Giardia* cysts and viruses in the source water," and requires a level of treatment equivalent to disinfection.

The SWTR establishes minimum requirements of the watershed control program as:

- Assessing the hydrology, land cover, and land use characteristics of the watersheds.
- Describing activities or characteristics of the watershed that may adversely impact source water quality.
- Monitoring and controlling these activities or characteristics.

In addition, the SWTR requires that the public agency responsible for watershed management demonstrates control over the watershed's land, either through land ownership or through agreements with private land owners. There must also be an annual survey by the primacy agency (in this case, DEP) that documents the effectiveness of the watershed control program.

EPA promulgated the Interim Enhanced Surface Water Treatment Rule (IESWTR) in December, 1998. The IESWTR builds on the SWTR, adding requirements of treatment and control for *Cryptosporidium*. The IESWTR adds the specific requirement that unfiltered water systems must maintain a watershed control program to minimize the potential for *Cryptosporidium* contamination, including identifying and monitoring watershed characteristics and activities that may have an adverse effect on water quality. In the IESWTR, EPA states, "it appears that unfiltered water systems that comply with the source water requirements of the SWTR have a risk of cryptosporidiosis equivalent to that of a water system with a well-operated filter plant using a water source of average quality."

DWSP strives to meet all the regulatory requirements set forth for a manager of an unfiltered public water supply as well as a steward of natural and cultural resources.

Table 2: Federal and State Laws and Regulations Affecting OWM Resource Protection Activities

Name	Citation	Regulatory Agency	Description
Safe Water Drinking Act	33 U.S.C. 1251 et seq	US EPA, MA DEP	Surface Water Treatment Rule, Interim Enhanced Surface Water Treatment Rule, and Long Term 2 Enhanced Surface Water Treatment Rule (LT2) are all parts of federal law that protect drinking water supplies.
MA Drinking Water Regulations	310 CMR 22.00	MA DEP	Promotes public health and general welfare by ensuring that public water systems in Massachusetts provide to the users thereof water that is safe, fit and pure to drink.
Federal Endangered Species Act	16 U.S.C. 1531 et seq.	US Fish & Wildlife Service	The purpose of the ESA is to conserve the ecosystems upon which endangered and threatened species depend and to conserve and recover listed species. Under the law, species may be listed as either Endangered or Threatened. Endangered means a species is in danger of extinction throughout all or a significant portion of its range. Threatened means a species is likely to become endangered within the foreseeable future.
MA Endangered Species Act	MGL c. 131 s. 23; 321 CMR 10.00	MA Division of Fisheries and Wildlife	Procedures and rules that establish a comprehensive approach to the protection of the Commonwealth's Endangered, Threatened, and Special Concern species and their habitats.
Federal Americans with Disabilities Act	Public Law 101-336.	US Department of Justice	The ADA prohibits discrimination and ensures equal opportunity for persons with disabilities in employment, State and local government services, public accommodations, commercial facilities, and transportation.
MA Wetlands Protection Act	MGL c. 131 s. 40; 310 CMR 10.00	MA DEP, Local Conservation Commissions	A public review and decision making process by which activities affecting wetlands are to be regulated in order to contribute to the following interests: protection of public and private water supply; protection of ground water supply; flood control; storm damage prevention; prevention of pollution; protection of fisheries; and protection of wildlife habitat.
MA Rivers Protection Act	MGL c. 258, Acts of 1996; 310 CMR 10.00	MA DEP, Local Conservation Commissions	Amendments made to Wetlands Protection Act to provide additional protection to the state's rivers.

Name	Citation	Regulatory Agency	Description
MA Forest Cutting Practices Act	MGL c. 132 § 40 to 46; 304 CMR 11.00	DCR Bureau of Forestry	Protects the benefits of forests through a permitting process. Applicable to timber harvesting on both public and private forestland, the FCPA regulates any commercial timber cutting of wood products greater than 25 thousand board feet or 50 cords on any parcel of land at any one time. This Act also requires the licensing of foresters and timber harvesters.
US Clean Water Act –National Pollution Discharge Elimination System (NPDES)Phase II Stormwater Rules	33 U.S.C. 1251 et seq.	US EPA, MA DEP	The Storm Water Phase II programs, through the use of NPDES permits, implements programs and practices to control polluted storm water runoff from municipal separate storm sewer systems and small construction sites. Phase II is intended to further reduce adverse impacts to water quality and aquatic habitat by instituting the use of controls on the unregulated sources of storm water discharges that have the greatest likelihood of causing continued environmental degradation.
MA Hazardous Waste Site Assessment/ Cleanup	MGL c. 21E; 310 CMR 40.0000	MA DEP	The Massachusetts Contingency Plan lays out a detailed process for when and how contaminated sites must be assessed and cleaned up.
MA Historical/ Archaeological Resource Protection	MGL c. 9 § 26 to 27C; 950 CMR 70.00	Massachusetts Historical Commission	Encourages all governmental bodies and persons considering action that may affect an historical or archeological asset of the commonwealth to consult with the Massachusetts Historical Commission to avoid any adverse effect to such asset.
Massachusetts Environmental Policy Act (MEPA)	MGL c. 30 §61-62H; 301 CMR 11.00	US EOEEA	Provides meaningful opportunities for public review of the potential environmental impacts of Projects for which action is required by an EOEEA agency, and to assist each Agency in using (in addition to applying any other applicable statutory and regulatory standards and requirements) all feasible means to avoid damage to the environment or, to the extent damage to the environment cannot be avoided, to minimize and mitigate damage to the environment to the maximum extent practicable.

Name	Citation	Regulatory Agency	Description
MA Outstanding Resource Waters	314 CMR 4.00	MA DEP	Waters with exceptional socio-economic, recreational, ecological and/or aesthetic values are designated as Outstanding Resource Waters (ORWs) by the MA Surface Water Quality Standards. ORWs include surface Public Water Supplies and their tributaries, wetlands bordering surface Public Water Supplies and their tributaries, certified vernal pools. Discharge of pollutants to a Massachusetts Outstanding Resource Water is severely restricted and requires special review by DEP.

Sources: DCR, MWRA, DEP, EPA, DOJ, and USF&WS.

1.4.3 Filtration Waiver

The combination of Quabbin and Wachusett Reservoirs' size, the watersheds' natural characteristics, and DCR's management activities were a cornerstone to the MWRA's ability to obtain filtration waivers for this water supply. The 412 billion gallon Quabbin Reservoir, with 75% of its watershed in permanently protected land, received a filtration waiver for the Chicopee Valley Aqueduct in 1991. The Wachusett Reservoir, which is smaller than Quabbin, has less protected open space and more development in its watershed, required more analysis by state and federal regulators prior to issuing a waiver for the entire watershed system.

In June, 1993, MWRA and MDC entered into an administrative consent order with the MA Department of Environmental Protection (DEP), which allowed the pursuit of a "dual track" for regulatory compliance with the SWTR for the Wachusett Reservoir. It required MWRA to design and build a filtration plant, unless MWRA could demonstrate with MDC that the system met the criteria for avoiding filtration and DEP determined that filtration was not required. After years of study and research on the needs of the water supply system, review of current information on water treatment effectiveness on pathogens of concern, disinfection byproducts, watershed protection and public health concerns, and input from the public and water supply and public health experts, MWRA concluded that an ozonation/chloramination plant would provide appropriate treatment of the water supply, and that adding filtration to the new plant for $180 million would not provide as much additional benefit as would using funds to rehabilitate old unlined cast iron pipes in the MWRA and local distribution systems.

DEP agreed with MWRA's approach in December 1998 after a hearing and comment period, and determined that filtration was not required for the DCR/MWRA system. EPA, however, did not agree and continued to prosecute the enforcement action previously filed under its SDWA "overfiling" rights, seeking to require MWRA to build a filtration plant, contending that the SDWA allowed no other option. The U.S. District Court ultimately concluded that the comprehensive strategy to improve drinking water proposed by MWRA and MDC/DWM, through watershed protection for Wachusett and Quabbin reservoirs, a new ozonation/ chloramination disinfection facility, and a community pipe rehabilitation program, sufficiently protects public health and cost-effectively improves drinking water quality. (Kurtz, 2000; *U. S. v. MWRA*, 97 F.Supp.2d 155).

The John J. Carroll Water Treatment Plant at Walnut Hill in Marlborough, MA came on-line in July, 2005. The effectiveness of this state-of-the-art facility and ultimately compliance with all safe water drinking regulations relies on OWM maintaining the integrity of the watershed as a barrier against contamination of the source waters. As strongly as any other justification, this relationship requires the level of detail embodied in this land management plan for the Quabbin Reservoir watershed.

1.5 Policy Framework

1.5.1 Land Management Planning and the MA Climate Protection Plan

The role of active land management is increasingly entering the discussion regarding long-term strategies for mitigating the negative effects of global climate change. The Massachusetts Climate Protection Plan was published in 2004, offering a course of action for the problems associated with climate change (for full text, see http://www.massclimateaction.org/pdf/MAClimateProtPlan0504.pdf). The expert assessment cited in this plan states:

> The International Panel for Climate Change (IPCC), a group sponsored by the United Nations and the World Meteorological Organization, representing more than 2,000 leading climate scientists, predicts an average temperature increase of 5-9°F by 2100, although a wider range of outcomes is possible. To put this number in perspective, only about 9°F separates the world at the beginning of the twenty-first century from the world at the end of the last Ice Age, more than 10,000 years ago.

Three of the major predictions in the climate protection plan are directly relevant to this Land Management Plan for a drinking water supply:

1. Extreme weather events, already a characteristic of New England, are likely to become more frequent and cause more damage under a changing climate.
2. Higher temperatures would accelerate evaporation and cause drier conditions and droughts, placing pressure on our water resources, which are already stressed by regional growth.
3. Climate change could have serious impacts on the state's diverse ecosystems and native species, and may encourage the spread of non-native species. (Commonwealth of MA, 2004)

Each of these issues is addressed in various sections of this Quabbin Land Management Plan (see sections on Disturbance (3.4), Water Yield (3.1.2; 4.1.2), and Invasive Species (5.5.5)). The Massachusetts Climate Protection Plan contains specific action objectives for land and forest management under Chapter 10, "Natural Resources Protection as a Climate Strategy", listed below. Specific DCR actions in response to each objective are shown in italics after each objective.

1. HOST WORKSHOPS ON THE POTENTIAL IMPACTS OF CLIMATE CHANGE ON NATURAL RESOURCES AND LAND MANAGEMENT. *DWSP will supplement statewide workshops on this issue by addressing questions through regular public workshops on land management generally held at least annually.*
2. PROMOTE A NEW FOREST VISION THAT INTEGRATES CARBON RESOURCE MANAGEMENT WITH OTHER NATURAL RESOURCE GOALS.
   - [SELECT TREES] THAT WILL INCREASE CARBON STORAGE AND SHEPHERD ADAPTATION TO CLIMATE CHANGE OVER TIME. *DWSP considers these factors whenever plantings occur and as a component in silvicultural decisions. The USDA Forest Service has provided the "Atlas of Current and Potential Future Distributions of Common Trees of the Eastern United States" (General Technical Report NE-265; Iverson et al., 1999), a useful reference for such decisions that indicates that yellow poplar, Virginia pine, sycamore, scarlet oak, southern red oak, blackjack oak, chestnut oak, post oak, and sassafras may become established or increase in abundance in Massachusetts as a result of predicted climate change.*
   - INCLUDE CARBON RESOURCE MANAGEMENT AS ONE CRITERION IN THE MANAGEMENT OF PUBLIC FORESTS. *This criterion is implicit in the overall management objective of maintaining dense, vigorous watershed forests. Wood from watershed management practices may sequester carbon when it is used to manufacture long-lived products such as furniture or houses, or when the carbon it releases when it is burned for heat or energy is recovered by*

regeneration or enhanced growth on the forests from which it was cut. Carbon management is also addressed through DWSP policies that require the retention of standing and fallen dead wood to meet snag tree and coarse woody debris habitat objectives.

3. CONTINUE OPEN SPACE PROTECTION EFFORTS. *DWSP continues to purchase critical parcels of land as well as conservation easements within its watershed boundaries, in order to enhance long-term water supply protection. These purchases, detailed in section 5.1, also add to the overall statewide open space protection efforts.*
4. DEVELOP AND IMPLEMENT A COMPREHENSIVE BIOMASS POLICY. *While it is outside the purview of DWSP to develop such a statewide policy, the agency is participating by providing forest inventory data and by pursuing the potential for using biomass to provide heat and power to DWSP administration buildings within the Quabbin watershed.*

1.5.2 Third-party "Green" Certification of State Forest Lands Management

The 1997 certification of Quabbin Reservoir watershed forestry practices was the first third-party, "green" certification of public lands management in North America. Certification provides third-party review and auditing of forest management practices for the long-term sustainability of their relationship to the environment and to the regional human economy. As the Quabbin certification approached its five-year renewal date, the Executive Office of Environmental Affairs (now the Executive Office of Energy and Environmental Affairs, EOEEA) decided to pursue a broader certification audit; on April 10, 2004, *all* state forest lands in Massachusetts became "green" certified. The Massachusetts state lands certification was granted by Scientific Certification Systems (www.scs1.com), an independent, third-party certification body accredited by the international Forest Stewardship Council (www.fsc.org). Certified lands in Massachusetts are managed by different agencies of the EOEEA, including DCR's Division of State Parks and Recreation (285,000 acres), the Department of Fish and Game's Division of Fisheries and Wildlife (110,000 acres), and DCR's Division of Water Supply Protection (104,000 acres). With this certification Massachusetts becomes the first state in which multiple forest management agencies have joined forces to earn certification of all publicly managed state forest land. Certification is an endorsement, but conditions for improvements in management practices must be attained within a five-year period for this endorsement to remain current and valid.

Final condition number 2002.9 in the MA Certification Evaluation Report requires that this plan for management of the Quabbin DWSP properties must include a determination of the percentage of OWM lands that fall under "High Conservation Value Forest" designation under category 4 (watershed values), and a description of the ways in which management of these lands is consistent with maintaining or enhancing HCVF attributes. On further discussion with the auditor, it was agreed that 100% of these properties meets the criteria for High Conservation Value Forest, and furthermore, that the management practices described herein are fully consistent with category 4 watershed values inasmuch as watershed protection is the priority for all lands under OWM management. The full MA certification report, including the details of these conditions is available online at www.mass.gov/envir/forest/default.htm.

1.5.3 Ecoregional Planning

Another condition in the MA Certification Evaluation Report (pre-condition DEM 2002.1) calls for the initiation of a landscape-level planning process - based on ecoregions - which are intended to provide a blueprint or framework for the development of more detailed site or property management plans. The first of the ecoregion guidance documents was produced in 2004 for the Lower Worcester Plateau (LWP) ecoregion, which includes Quabbin Reservation.

This document - titled *Landscape Assessment and Forest Management Framework: Lower Worcester Plateau Ecoregion in Massachusetts* - identified 14 major management goals for the LWP. These were arranged by category, and include:

Conservation of Biological Diversity:

1) *Enhance and expand the occurrence of contiguous blocks of early and late successional habitats, especially oak types, within the Ecoregion.*
2) *Establish a network of forest reserves in the LWP Ecoregion that provides a wide range of ecological and social benefits.*
3) *Protect the largest, most intact, biologically significant, or most-threatened forest blocks in the ecoregion.*

Forest Conservation:

4) *Prevent new occurrences of non-native, invasive plant species and identify and control existing invasive threats to rare plant populations.*
5) *Restore degraded forests (e.g., formerly high-graded stands, plantations, etc.) to a more natural and native condition.*
6) *Minimize the impact of hemlock wooly adelgid on the forest within the ecoregion.*
7) *Minimize high-grading by encouraging the application of sustainable forest management and conservation biology principles.*

Soil and Water Conservation:

8) *Enhance the protection of the ecoregion's water supplies via improved land conservation and forest management.*
9) *Reduce damage resulting from ORV/ATV activity within the ecoregion.*

Socio-Economic Factors:

10) *Utilize existing state and federal renewable energy programs to support a significant biomass application within the ecoregion.*
11) *Increase the amount of land enrolled in Chapter 61, the Forest Stewardship Program, or other programs that provide significant incentives for landowners to keep land in forest cover.*
12) *Provide more equitable compensation to rural municipalities for the costs of having state lands within their communities.*
13) *Strengthen the regional forest product economy by creating a more consistent and predictable flow of forest products to local forest industries.*
14) *Assure the long-term protection of cultural resources in the LWP ecoregion.*

The ecoregion guidance documents are intended to identify the primary management needs for the ecoregion as a whole, and thus they provide general goals that managers attempt to address when developing individual property management plans. While it is not intended that each plan address every goal, the Quabbin LMP addresses almost all of the goals in the LWP ecoregion guidance document.

Perhaps the greatest contribution that the Quabbin Reservation makes towards the goals of the LWP Ecoregion document is in providing large blocks of intact forest (goal #3), much of which is comprised on native oak stands (goal #1). These stands are carefully managed through sustainable practices that incorporate wildlife and other conservation biology principles (goal #7). Where appropriate, degraded or non-native stands are restored to a more natural or native condition (goal #5). Research and control measures for forest pests like Hemlock Wooly Adelgid are also employed (goal #6), as are surveys and interventions aimed at controlling invasive plants (goal #4). The DWSP designates forest reserve areas within its land holdings (goal #2), and also identifies and protects cultural resources (goal #14).

The vast majority of the forest management work conducted on Quabbin is done through contracts with private loggers, thus providing a significant contribution to the regional forest product economy (goal #13). And until recently, the DWSP funded the preparation of forest management plans for private landowners on the watershed, through its Private Lands Stewardship program (goal #11). Plans are also underway to establish the first biomass heating system in a DCR facility at the Quabbin administration building (goal #10).

Finally, all the forest and land management work being planned and conducted at Quabbin is geared towards the long-term protection of water quality, since the reservoir provides the primary source of drinking water for almost half the population of Massachusetts. Thus, goal #8 essentially constitutes the DWSP's primary mission.

In summary, this update of the Quabbin Land Management Plan not only is consistent with the goals of the LWP Ecoregional guidance document, but should make substantial contributions to the furthering of those goals within the Lower Worcester Plateau ecoregion.

1.5.4 Forest Reserves, Large and Small

Forest reserves are portions of state lands where commercial harvesting of wood products is excluded in order to capture elements of biodiversity that can be missing from harvested sites. Small (patch) reserves will conserve sensitive, localized resources such as steep slopes, fragile soils, and habitat for certain rare species that benefit from intact forest canopies. Large (matrix) reserves are designed to represent the diversity of relatively un-fragmented forest landscapes remaining in Massachusetts today. Matrix reserves may support a wider diversity of tree sizes and ages than typically occurs on harvested sites, as well as structures and processes associated with extensive accumulations of large woody debris that may be absent from harvested sites.

Matrix reserves will ultimately include a wide range of tree sizes and ages, from large, old trees 200-500 years old, to small, young trees that occur in open gaps where old trees have died or been blown over. The trunks and branches of large trees that are toppled during wind storms will accumulate as large woody debris in the forest, and will support decades or even centuries of activity by micro-organisms and invertebrate wildlife that occupy, feed upon, and ultimately break down these massive stores of organic material.

The EOEEA agencies responsible for managing state-owned forestlands (DCR Division of State Parks and Recreation, DCR Division of Water Supply Protection, and DFG Division of Fisheries and Wildlife) have established nine matrix reserves (**Table 3**) that represent the diversity of forest ecosystems that occur within the remaining, relatively un-fragmented forest landscapes of Massachusetts.

Table 3: Large (Matrix) Forest Reserve Sites on State Land

Site Name	Ecological Type	State Lands	Acres
Mt. Greylock	Taconic Mountains ELU (Ecological Land Unit) group 9	Portions of the Mt. Greylock State Reservation	8,500
Mohawk/Monroe/Savoy	Southern Green Mountains	Portions of the Monroe State Forest	7,100
Chalet	Berkshire/Vermont Upland Ecoregion. ELU group 8	Portions of the Chalet, Stafford Hill, and Eugene Moran Wildlife Management Areas, and portions of the Windsor State Forest.	7,112
Mt. Washington	Taconic Mountains ELU group 9	Portions of the Mt. Washington State Forest, and portions of the Jug End State Reservation & Wildlife Management Area	7,155
Middlefield / Peru	Berkshire/Vermont Upland Ecoregion. ELU group 7a	Portions of the Middlefield State Forest.	2,900
Otis	Berkshire/Vermont Upland ELU group 6b	Portions of the Otis State Forest.	769
East Branch Westfield River	Hudson Highlands Ecoregion ELU group 4a	Portions of the Gill Bliss State Forest, and portions of the Hiram Fox Wildlife Management Area.	2,638
Cunningham Pond	Worcester-Monadnock Plateau Ecoregion	Portions of the Ware River Watershed Forest.	3,029
Myles Standish	Cape Cod/Islands Ecoregion	Portions of the Myles Standish State Forest and portions of the Sly Pond Natural Heritage Area.	11,000
TOTAL AREA			**50,203**

The EOEEA agencies have established the following goal, objectives, and benefits for matrix reserves.

Goal: Capture elements of biological diversity that can be missing from harvested sites.

Objectives:

- Retain wood fiber that is typically extracted from the forest ecosystem.
- To the greatest degree possible, allow natural disturbance processes to determine the structure and composition of the forest ecosystem.
- Facilitate biological monitoring to establish baseline data on the species, natural communities, and ecological processes that occur in forest ecosystems reserved from commercial timber harvesting.

Benefits:

- Allow comparison of species, natural communities, and ecological processes on harvested sites with sites reserved from harvest of wood products.
- Provide late-successional forest habitats for wildlife that represent the diversity of forest ecosystems in Massachusetts.
- Inform management of harvested sites with knowledge of structural attributes that develop on reserve sites.
- Provide unique recreational and aesthetic opportunities in biologically mature forest habitats that will develop over time in reserves.

Within DWSP properties surrounding Quabbin Reservoir, approximately 12,000 acres have been identified as "small reserves", consisting of steep slopes, wetlands, rare species habitat, islands, identified natural areas such as the Pottapaug Pond Natural Area, sensitive cultural resource areas, and areas that are inaccessible for a variety of reasons. See section 5.5.4 for further details; for more information on statewide reserves, go to www.mass.gov/envir/forest/pdf/whatare_forestreserves.pdf.

1.6 DCR/DWSP/OWM Planning Process

DWSP is engaged in an on-going planning process, consistent with legislative, regulatory, and court mandates, to maintain the watershed system's superior water quality. There are three critical plans prepared for each watershed via the DWSP planning process, including a Public Access Management Plan, a Land Management Plan, and a Watershed Protection Plan.

The Public Access Management Plan describes the management policies that allow people to recreate on DWSP lands while still protecting water quality. The Land Management Plan is a thorough description of the watershed's physical features, the natural resources on DWSP property, and the variety of techniques used by the agency to enhance water quality, including land protection, forest and wildlife management, cultural resource protection, and the protection of biological diversity. Implementation of the Land Management Plans is a key requirement for the continued independent "green" certification of DWSP forestry activities. The Watershed Protection Plan takes information from the Public Access Plan and Land Management Plan and integrates water quality monitoring findings and other studies to create an action plan that is the basis for DWSP's annual work plan and budget. The Watershed Protection Plan acts as an "umbrella," encompassing all efforts by DWSP that affect both public and private lands in the quest to provide the highest quality drinking water in the world.

Additional studies and reports utilized in the Watershed Protection Plan include: the Land Acquisition Plan, DWSP's guide to purchasing properties that are critical to long-term water quality protection; annual Water Quality Reports and basin specific Environmental Quality Assessments that identify water quality trends, link problems to sources of contamination, and develop prioritized goals for corrective actions; and Emergency Action Plans that detail the necessary steps and chain of command required in case of a catastrophe associated with the reservoirs. Stormwater Management, Agriculture, and Hazardous Materials Emergency Response are examples of topics that have come under special study.

This comprehensive approach to watershed planning has made it possible for MWRA to maintain a waiver from federal filtration requirements and make the Office of Watershed Management a national model. While consultants are utilized when necessary for specific expertise, the vast majority of these plans and outreach material are developed by DWSP staff. **Table 4** provides a summary of the status of DWSP's plans, including the current version, term, and history. Recent plans, fact sheets and newsletters are available on-line at www.mass.gov/dcr/waterSupply/watershed.

Table 4: DCR/DWSP/Office of Watershed Management Planning Summary

Type of Plan	Latest Publication	Term	Next Planned Revision	History (Consultant)
Watershed Protection Plans				
Quabbin Reservoir/Ware River	2000	5-8 years	2008	1991 (Rizzo)
Wachusett Reservoir	2003	5 years	2008	1991 (Rizzo), 1998 (CDM)
Sudbury Reservoir System	1997	As Needed (Emergency Reserve – WPP not required)		(CEI)
Land Management Plans[1]				
Quabbin Reservoir	1995	10 years	2007	1961, 1972, 1986
Ware River	2003	10 years	2013	1986
Wachusett Reservoir	2001	10 years	2011	
Sudbury Reservoir System	2005	10 years	2015	
Public Access Management Plans				
Quabbin Reservoir	1998	5-10 years	2005	1988
Ware River	2000	5-10 years	2010	1988
Wachusett Reservoir	2003	5-10 years	2013	1996
Sudbury Reservoir System	2002	5-10 years	2012	1994
Other Plans and Reports				
DWSP Fiscal Year Work Plan	2006	1 year	2007	2005
Land Acquisition Plan[2]	2006 (draft)	5 years	2011	1998
Emergency Action Plans (w/MWRA)	2005 Review	Annual Review	2006	1993–1995 (GZA and GEI)
Stormwater Management	1999	As Needed		(CDM)
Agriculture	1998	As Needed		(CEI)
Highways/Railways Hazardous Material Release Control Project	1998	As Needed		(Rizzo)
Hazardous Materials Emergency Response Plans	1997	As Needed		(CEI)
Water Quality Reports				
Annual Water Quality Report	2007	1 Year	2008	Annually since 1987
Environmental Quality Assessments (Replaced Sanitary Surveys in 2000)	2004	5 years	On-going (1 sub-basin/year)	Sanitary Surveys: 1988–2000. EQAs: 2000-present

[1] Cutting plans are developed annually to guide specific forestry activities.
[2] A list of properties is developed semi-annually for review by the MWRA Board of Directors.
All plans produced by DWSP staff unless noted otherwise.

1.7 Land Management Planning and Public Review and Input Process

1.7.1 Planning and Advisory Committee Mandate

Chapter 92A½, Section 13 establishes the Quabbin watershed advisory committee (QWAC), its membership and its purpose (see **Appendix 9.2.4**). Chapter 92A½,: Section 16 regarding "periodic watershed management plans" states that the agency shall periodically "produce watershed management plans, which shall have been prepared with the participation of a professionally qualified forester and the appropriate watershed advisory committee" (see **Appendix 9.2.3**). The Quabbin Watershed Advisory Committee has established a subcommittee on forestry and wildlife management. This subcommittee works with the Natural Resources and Quabbin Section staff to develop and review drafts of the land management plans for Quabbin.

1.7.2 Public Input to DCR/DWSP's Land Management Plans

Public outreach is an important element of the success of DWSP's watershed protection efforts. As managers of public land, DCR/DWSP staff has a responsibility to solicit public input in order to address concerns, explain existing management practices, and integrate new ideas, when practical, in order to provide the best possible protection for the drinking water supply. Each plan seeks input from a variety of perspectives—such as legislatively mandated watershed advisory groups, visitors, abutters, and user interest groups—through public meetings, the press, and the DCR website. In addition to hearings and informational meetings on plans, DWSP supports an ongoing discourse with the public on water supply protection strategies through individual contact with interpretive staff and DWSP Watershed Rangers, implementation of the Watershed Protection Act, municipal technical assistance, fact sheets, and the bi-annual newsletter *Downstream*.

The goals of the Division's public input process for land management planning are to:

- Regularly solicit public input in order to better understand the broad range of current public issues and concerns regarding forest and wildlife management, so that the Division can better integrate these concerns into protection strategies and the development of goals and objectives for maintaining watershed integrity.
- Educate the public regarding the development of goals and objectives of the Division with regard to its land management program.
- Improve the understanding of both agency staff and the public regarding the technical aspects of forest and wildlife management on the Division's watersheds.
- Educate the public regarding Division implementation of the land management program, in order to address concerns and retain public confidence in these practices.

1.7.3 Monitoring and Regular Revisions to the Quabbin Land Management Plan

DCR and MWRA are dedicated to watershed protection as part of a multi-barrier approach to protecting drinking water quality. Updating a plan provides the opportunity to consider the implementation of DWSP's programs, integrate increased knowledge of water quality protection and watershed sources of concern, and set a focused watershed protection agenda. Among the issues considered by DWSP are changes in population, trends in recreation and public access, development of new technologies, and advances in scientific research. The implementation of these plans is also considered an opportunity to test the principles on which they are based. Through both internal and outside monitoring of the Division's practices, it periodically becomes desirable to make adjustments to plans within the current management period. This adaptive management approach allows for fine-tuning of practices based on new information. However, as these plans are subject to public review and comment prior to their

implementation, any proposed changes will be presented at a public meeting prior to being incorporated in the plan or its implementation. These public meetings will be scheduled on an annual basis and will include reporting on implementation progress, findings from monitoring efforts, and proposals for refinements to the plan based on these monitoring efforts. In addition to announcing these meetings to the general public, QWAC and the scientific and technical advisory committee described below will be encouraged to attend.

Over the past 5-6 decades of management of the lands surrounding Quabbin Reservoir, monitoring of the effects of implemented practices on natural and cultural resources has occurred regularly, although limited somewhat by budget and staffing. This monitoring has included establishment of permanent Continuous Forest Inventory plots and their remeasurement consistently every 5 or 10 years (see section 2.4.2.3). Regeneration and the effects of browsing by deer have been monitored annually since 1989 (see Appendix IV), and a variety of techniques are being tested for monitoring moose populations (see section 5.4.4.5.3). The Environmental Quality staff have monitored water quality at multiple locations throughout the watershed on an annual or monthly or storm-based schedule since shortly after the establishment of the reservoir. A mix of Natural Resources, Forestry, Environmental Quality, and Watershed Maintenance staff provide regular monitoring of the condition and sufficiency of access roads, gates, bridges, culverts, and related infrastructure. Wildlife populations have been monitored using a wide variety of methods for many years (for example, beaver populations on the Prescott Peninsula have been surveyed regularly since 1952 – see sections 2.5.2.2 and 5.4.4). Rare plants are identified on an ongoing basis, as encountered, and then monitored by DWSP Natural Resources staff as well as volunteers from the New England Wild Flower Society on a regular basis. Rare wildlife is surveyed regularly by a combination of DWSP Natural Resources and Natural Heritage and Endangered Species staffs, and recommended practices to protect and enhance these populations have been upgraded recently through collaborative review of management effects. In addition to monitoring efforts involving DWSP staff directly, the agency relies on reports from researchers who conduct both short term and long term studies of a wide variety of watershed resources and processes. Their work is frequently published in refereed scientific journals, but is also available to the public by request.

As a result of the terrorist attacks of September 11, 2001, all public water suppliers were forced to increase their focus on monitoring and improving the security of the public water supply. The security of the water system is among the highest priorities for the Division and the MWRA. The Division's security policies are periodically reviewed in order to achieve the goal of providing a safe and secure water supply system through a system that is constantly updated in response to new information. Security of the water system is designed to be comprehensive – source to tap – but flexible enough to adjust to a range of potential threat conditions. Regular monitoring and updating of security as it relates to such infrastructure as access roads or is a component of the land management planning process.

1.7.4 Scientific and Technical Review (QSTAC)

In the fall of 1996, the MDC/DWM assembled the first meeting of the Quabbin Science and Technical Advisory Committee. This committee includes professional forest, wildlife, and natural resource researchers and managers from state agencies (DCR/DWSP; DCR Bureau of Forestry; Department of Fish and Game, Division of Fisheries and Wildlife), the University of Massachusetts Departments of Natural Resources Conservation and Civil and Environmental Engineering, Harvard Forest, the USDA Forest Service, Mount Holyoke College, Amherst College, the Institute of Ecosystem Studies, USGS, Massachusetts Audubon Society, the New England Small Farms Institute, the MA Natural Heritage and Endangered Species Program, and Hampshire College.

The Science and Technical Advisory Committee was formed to convene as needed to address major natural resources and watershed management issues and changes in the Land Management Plan, and to advise DWSP in the development and implementation of scientific research to address concerns at Quabbin. The committee is intended to function as the "bridge" between professional research and management. In addition to general advice, the committee has assisted in the following special issues: setting of research priorities, development of standards for research quality assurance and control, subwatershed modeling, determination of appropriate sizes for regeneration openings, decisions with regard to future designations of lands reserved from management, management considerations for the Pottapaug Natural Area, and the development of a policy for the treatment of watershed areas affected by the hemlock woolly adelgid. The committee met annually from 1996 through 2000 and sub-groups have been called upon occasionally to address current issues.

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2 Description of Quabbin Reservoir Watershed Resources

2.1 DCR/MWRA Water Supply System

2.1.1 System Description

The Department of Conservation and Recreation, Division of Water Supply Protection, Office of Watershed Management and the MWRA supply drinking water to 40 communities in the metropolitan Boston area. The Town of Clinton also draws water from Wachusett Reservoir, independent of the MWRA transmission and treatment system. Two communities near Wachusett Reservoir, Worcester and Leominster, may also withdraw water from the system for emergency supply. In addition, three communities southwest of Quabbin Reservoir (Chicopee, South Hadley Fire District #1, and Wilbraham) obtain their water directly from this reservoir through the Chicopee Valley Aqueduct. MWRA is responsible for treatment and transmission, while the Division is responsible for collection and safe storage of water, protection of reservoir water quality, and management of the watersheds.

Figure 1 presents a system schematic. Quabbin Reservoir, the Ware River, and Wachusett Reservoir are the active water supply sources for the metropolitan Boston water system. Ware River water is transferred seasonally to Quabbin Reservoir, while Quabbin Reservoir water is transferred regularly to Wachusett Reservoir through the Quabbin Aqueduct. Wachusett Reservoir is the terminal supply reservoir. Water is withdrawn through the Cosgrove intake at the eastern end of Wachusett Reservoir, and is carried by the Cosgrove Tunnel to the distribution system. The Wachusett Aqueduct provides redundancy to the Cosgrove Tunnel; it was used during the winter of 2003-2004 to allow connections to be made to MWRA's new Walnut Hill Treatment Plant.

The Sudbury and Foss (Framingham #3) Reservoirs are the emergency reserve water supplies for this system. There are three emergency conditions that would require the use of the Sudbury System: 1) Wachusett Reservoir is declared non-potable; 2) there is an inability to convey water from the Wachusett Reservoir to the MWRA system (e.g., failure of the Hultman Aqueduct, Southborough Tunnel, or the City Tunnel); or 3) a serious drought occurs.

Depending on the situation, the Sudbury Reservoir would be used either as a primary source of water supply, as a pass through of Wachusett Reservoir water, or as a supplemental source to the Quabbin and Wachusett Reservoirs. The past decade's withdrawals from each source water supply are summarized in **Table 5.**

Table 5: DWSP Watershed Areas and Withdrawals from System Sources, 1990-2000

Source	Watershed Area[1]		Average Annual Outflow[2] (mgd)	Average Annual Withdrawal (mgd)
	Sq. miles	Acres		
Ware River (MWRA Intake)	96	61,740	110	8.08[3]
Quabbin Reservoir	187	119,940	195.2	137.9
Wachusett Reservoir	117	74,890	127.4	123.1
Total DCR/MWRA Water Supply System	401	256,570	432.6	261

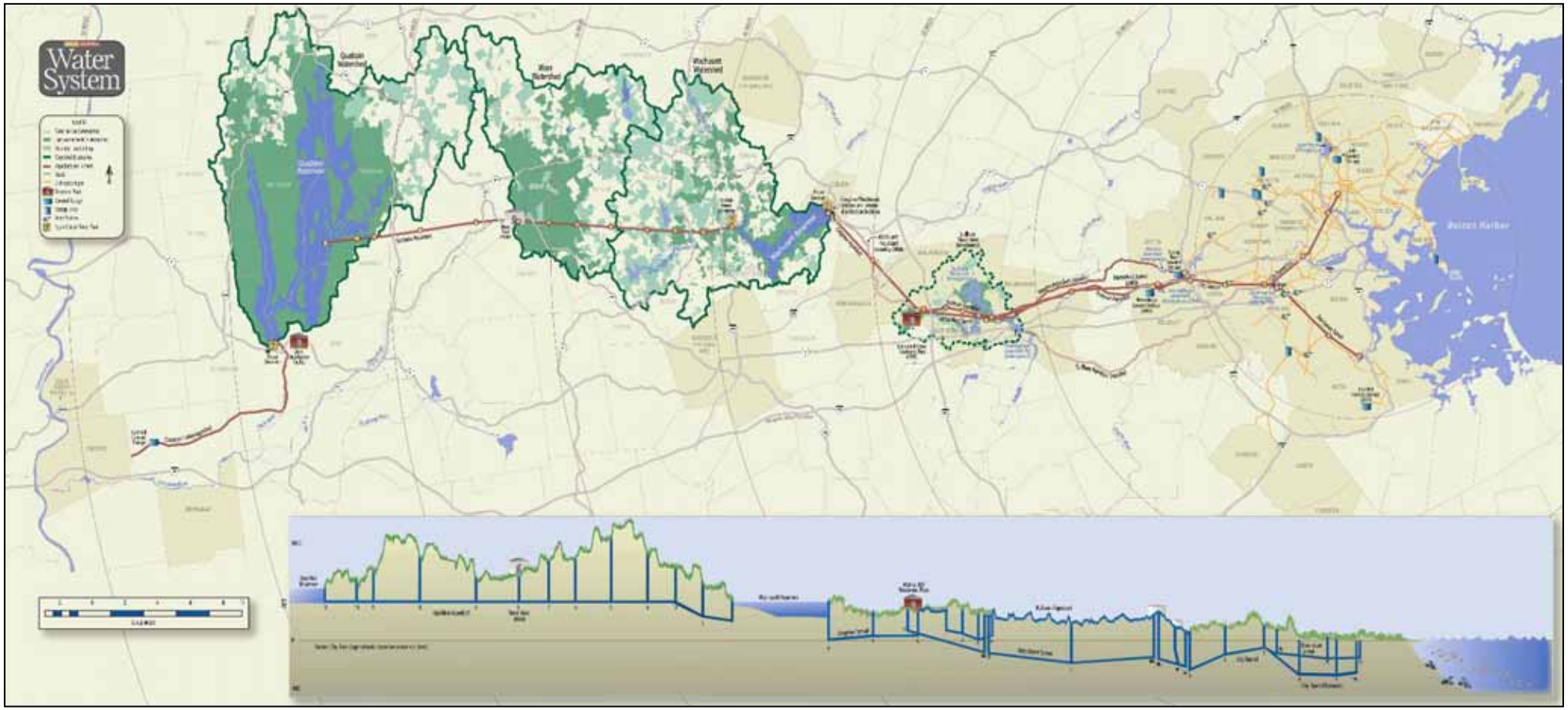
Source: Watershed Statistics – DCR/DWSP/OWM GIS; Water Withdrawal Statistics: MWRA, 2003

[1] Including area of reservoir surface for Quabbin Reservoir and Wachusett Reservoir.

[2] Outflow includes withdrawals and downstream releases

[3] This is not a supply but a transfer to Quabbin Reservoir.

Figure 1: MWRA Water Supply System Schematic



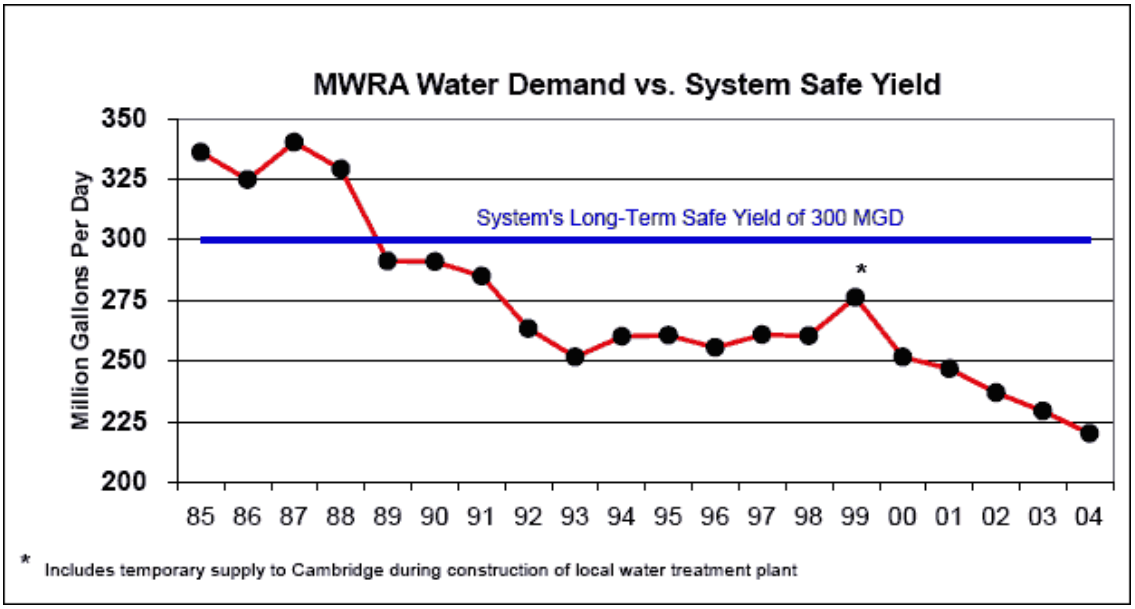
2.1.2 Safe Yield Estimation Model

Over the years, models and plans have been developed and refined to evaluate the MWRA system capacity. A Safe Yield Model was developed in the early 1980s that simulated inflow and outflow of water into the reservoirs using data for fifty years. It concluded that the safe yield was 300 million gallons a day (mgd).

Demand on this system was 225 mgd in 2005. This figure follows a fifteen year trend of diminishing water use in metropolitan Boston (**Figure 2**) and reduced MWRA demand, which had peaked at close to 350 mgd in the early 1980s. According to the MWRA, this reduction in average water use has been achieved through:

1. Vigorous leak detection and repair efforts on MWRA and community pipes.
2. Retrofitting 370,000 homes with low-flow plumbing devices.
3. A Water Management Program for businesses, municipal buildings and nonprofit organizations.
4. Extensive public information and school education programs.
5. A change in the state plumbing code requiring new toilets to be 1.6 gallon per flush.
6. Meter improvements that helped track and analyze community water use.
7. New water-efficient technology that has created reductions in residential use.
8. Water pipeline replacement and rehabilitation projects throughout the MWRA and community systems.

Figure 2: MWRA Water Demand vs. System Safe Yield



Source: MWRA

Maintaining the successful watershed management and water conservation programs will keep an adequate amount of excellent quality drinking water available to the MWRA user communities for the foreseeable future.

2.1.3 Quabbin Reservoir

2.1.3.1 Morphology and Bathymetry

The Quabbin Reservoir is a long reservoir with two main longitudinal sections linked by a narrow channel, the Enfield Channel. Morphometric characteristics comparing the Quabbin Reservoir with the Wachusett Reservoir are presented in **Table 6**. The bathymetry of a reservoir is a measurement of its depth from the water surface (generally at maximum elevation, i.e., when the reservoir is at its fullest), and is an expression of the topography of the reservoir floor. At full elevation of 530 feet above mean sea level, the deepest point in the Quabbin Reservoir is 151 feet below the surface, and the average depth is 45 feet. A bathymetric profile of the reservoir is shown in **Figure 3.** This bathymetry was derived from terrain elevations surveyed in the 1920s, in advance of the construction and filling of the reservoir. These surveyed data consisted of 140,480 elevation points, mapped out on 81 individual canvas map sheets overlapping the reservoir, a dataset that was recently converted to a digital reservoir elevation geodatabase.

Table 6: Morphology of Quabbin and Wachusett Reservoirs

Attribute	Quabbin Reservoir	Wachusett Reservoir
Volume Capacity	412 billion gallons[1]	65 billion gallons
Surface Area	38.4 square miles	6.5 square miles
Watershed Area	187 square miles	107.69 square miles
Shoreline	181 miles (61 on islands)	37 miles
Length	18 miles	8.5 miles
Maximum Width	3 miles	1.1 miles
Mean Width	1.5 miles	0.7 miles
Maximum Depth	151 feet	128 feet
Mean Depth	45 feet	49 feet
Normal Operation Range	520-530 feet	387-392 feet
Intake Depth[2]	442 feet[3]	364 & 345 feet
Overflow Elevation	530 (528) feet[4]	395 feet

Source: (DCR/DWSP – Civil Engineers Records, 2000)

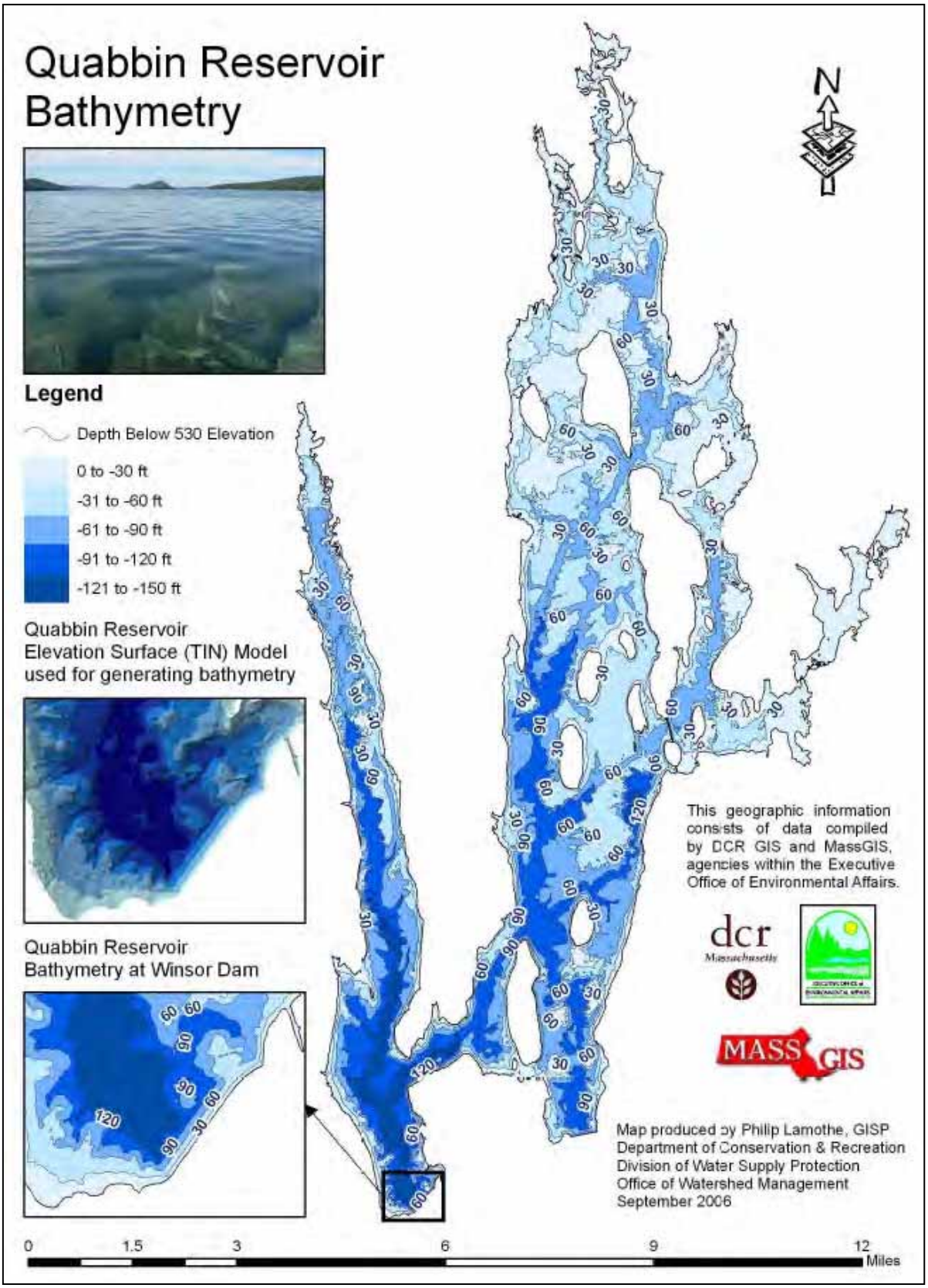
[1] This volume is based on an overflow elevation of 530 feet

[2] Datum used is Boston City Base (BCB) which is 6.049 feet lower than USGS 1929 datum used for topographic mapping.

[3] Intake for Quabbin Reservoir is for Quabbin Aqueduct. This is the elevation between the portal invert and the shaft floor.

[4] When stop logs are in place the overflow elevation is 530 feet. When the logs are removed the elevation is 528 feet.

Figure 3: Quabbin Reservoir Bathymetry



2.1.3.2 Inflows and Outflows

Inflows and outflows for Quabbin Reservoir are listed in **Table 7;** outflows are listed in **Table 8**. There are currently two continuous stream gauging locations within the Quabbin Reservoir watershed: the East Branch of the Swift River (1937-present), and the West Branch of the Swift River (1995-present). There is also a long stream gauging record at Cadwell Creek (1961-1997), which was discontinued in 1997. Tributary inflows were estimated for this assessment by doing a stream gauge transposition using the flows recorded by the gauges at the East Branch of the Swift River and Cadwell Creek.

Direct precipitation accounts for almost 30% of the average annual inflow. Inflows from Quabbin Reservoir's main tributary, the East Branch of the Swift River, and direct inflow follow direct precipitation in magnitude and, combined, account for about 34% of the annual inflow (on a long-term basis). Ware River transfers are also a significant source of inflow, at about 9% of the annual inflow.

The largest outflow from Quabbin Reservoir is the Quabbin Aqueduct withdrawal for transfer into Wachusett Reservoir, which accounts for more than 60% of water that leaves the reservoir. Other significant outflows are evaporation and downstream release to the Swift River, which together account for another ~30% of the outgoing water. Other smaller outflows include Chicopee Valley Aqueduct withdrawals for the Chicopee Valley Service Area and the flow over the reservoir's spill way, which occurs when the reservoir is full or almost full. In 1999, water transfers to the City of Worcester were additional outflows from the system.

DWSP and MWRA may divert water from the Ware River watershed at the Ware River Intake (Shaft 8) either to the Quabbin Reservoir or the Wachusett Reservoir through the Quabbin Aqueduct. The water enters the system at Shaft 8 on the Quabbin Aqueduct in the town of Barre, Massachusetts. Under normal operating conditions, the Ware River water flows to the Quabbin Reservoir through the aqueduct and is discharged at Shaft 11A, where the baffle dams force the water to flow several miles to reach Shaft 12 of the Aqueduct or further to the Chicopee Valley Aqueduct. It takes 3-4 years for water entering the Reservoir at Shaft 11A to travel to Shaft 12. In the past twenty-five years, there have been twenty-one annual diversions directly from the Quabbin Reservoir to the Wachusett Reservoir, and eighteen annual diversions from the Ware River intake to the Quabbin Reservoir. Currently, water transfers from the Quabbin Reservoir account for over 50% of the average annual inflow to Wachusett Reservoir. Transfers of approximately 550 mgd are made as needed to maintain the Wachusett Reservoir surface levels. These transfers occur primarily in the summer and fall months, are not continuous, and last for a period of several weeks at a time.

2.1.3.3 Hydrodynamics

A reservoir's hydrodynamics refers to the characteristic fluid motions of its waters during different seasons, under the range of local meteorological conditions (prevailing winds, temperature, storm events) and as influenced by the bathymetry and intricacies of the basin's shape. Residence time for reservoir waters, determined through hydrodynamic analysis, can influence risks associated with the transport of suspended sediments, pathogens, or other pollutants. The average residence time for water in the Quabbin Reservoir is about 4 years, defined generally as the reservoir volume divided by the annual inflows.

The reservoir is dimictic, turning over or mixing completely in the fall (usually in October), and again in spring in the period immediately following ice-out (usually in April). Quabbin develops some ice cover, usually between January and March, but occurring as early as December or as late as April. Inflows tend to move into different depths depending on seasonal temperature differences between the tributaries and

the reservoir. Tributary inflows are typically warmer than the reservoir in the spring and therefore enter the reservoirs' epilimnion (stratified lakes are described as having three zones: the upper epilimnion, the metalimnion (commonly called the thermocline), forming a boundary between waters of different temperature; and the bottom hypolimnion). In the summer and fall, tributary water is generally cooler than the reservoir's water and enters the reservoir below the epilimnion.

Table 7: Inflows to Quabbin Reservoir

Inflow Sources	Area (sq. mi.)	Annual Flow (cfs)	Annual Flow (mgd)	Annual Flow (%)
Direct Precipitation to Reservoir Surface	38	125	81	28
Ware River Transfers	96	39	25	9
Direct Inflow	40	78	51	17
East Branch Swift River	44	75	49	17
West Branch Swift River	12	24	16	5
Middle Branch Swift River	11	21	14	5
East Branch Fever Brook	9	17	11	4
West Branch Fever Brook	5	9	6	2
Hop Brook	5	11	7	2
Dickey Brook	4	8	5	2
Other tributaries	20	40	26	9

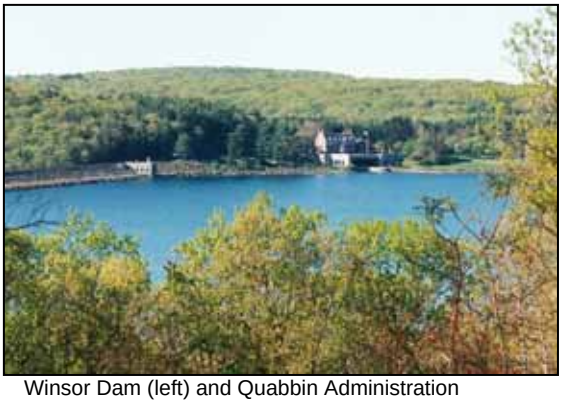
Table 8: Outflows from Quabbin Reservoir

Outflow Sources	Average Flow (cfs)	Average Flow (mgd)	Average Flow (%)
Quabbin Aqueduct	238	154	63
Chicopee Valley Aqueduct	18	12	5
Evaporation	68	44	18
Downstream release	42	27	11
Spillway	9	6	2

2.1.4 Overview of Quabbin Water Works

2.1.4.1 Winsor Dam and Goodnough Dike

Winsor Dam, located next to the Administrative Building, was built between 1935 and 1939. It is 2,640 feet in length, 35 feet wide at the top and 1,100 feet wide at the bottom, and required 4 million cubic yards of fill. It was named for Frank E. Winsor, the Chief Engineer for the Metropolitan District Commission from 1926 until his death in 1939. Winsor Dam impounds the waters of the Swift River, the primary source for the Reservoir, which first filled to the height of the spillway on June 22, 1946, reaching its full elevation volume of 412 billion gallons at that time.



Winsor Dam (left) and Quabbin Administration building (right).

Goodnough Dike

Goodnough Dike was built between 1933 and 1938. The Dike is 2,140 feet in length, 35 feet wide at the top and 878 feet wide at the bottom and contains 2.5 million cubic yards of fill. The Dike impounds the waters of Beaver Brook, which formerly flowed north through Morton and Sunk Ponds to the East Branch of the Swift River. It is considered a "dike" because it prevents the overflow of the lowlands surrounding Beaver Brook, rather than directly damming that tributary's flow. The Dike was named after the Metropolitan Water and Sewer Board's chair during 1921, X. Henry Goodnough.

2.1.4.2 Outlets and Aqueducts

Water leaves Quabbin Reservoir by gravity through two outlets: Shaft 12, which is the entrance to the Quabbin Aqueduct, and at the intake for the Chicopee Valley Aqueduct in front of Winsor Dam.

During the 1930s, the Wachusett-Coldbrook tunnel, which brought water from the Ware River to the Wachusett Reservoir during high flow periods, was extended westward to the Swift River. Shafts 11A and 12 connect this extension, known as the Quabbin Aqueduct, to Quabbin Reservoir. It is a two-way tunnel: floodwater can be skimmed and sent west from the Ware River to the Quabbin Reservoir as needed during eight months of the year, entering Quabbin at Shaft 11A, or water can be sent from Quabbin Reservoir to the Wachusett Reservoir, leaving Quabbin at Shaft 12 and flowing east through the same aqueduct. Ware River waters entering Quabbin Reservoir at Shaft 11A are diverted north around Mount Zion by baffle dams, allowing the settling of sediments and the mixing of these waters before they leave Quabbin Reservoir at Shaft 12.

Water from the Quabbin Reservoir flows through the Quabbin Aqueduct from the Northeast side of the Quabbin, up a grade to the Ware River Diversion in South Barre, Massachusetts, and then down grade to the Wachusett Reservoir through a power station near the Oakdale section of West Boylston, Massachusetts. This flow occurs by natural siphon action, the high point in the siphon being at the Ware River Diversion. At full elevation, the water surface of the Quabbin Reservoir is about 530 feet above mean sea level (MSL), while the water surface of the Wachusett Reservoir is about 384 ft above MSL, and the water surface of the Ware River Diversion is about 660 ft above MSL.

A natural siphon can only lift water about 30 feet, so the aqueduct is several hundred feet underground in several places so that the water head is only about 25 feet within the suction side of the aqueduct. The siphon starts at the Ware River Diversion by feeding the river water into the aqueduct. If the aqueduct branch that goes to the Wachusett Reservoir is closed (the Wachusett-Coldbrook branch), the Ware River water feeds the Quabbin Reservoir for storage. If the Wachusett branch is open, the water flows in both directions. Once the Wachusett branch begins to create sufficient suction as it fills, the Ware River Diversion inlet is closed and the water flow from the Quabbin to the Wachusett Reservoirs continues as a natural siphon.

The Quabbin Aqueduct, at 24.6 miles in length is one of the longest tunnels in the world and just ½ mile short of the Hetch Hetchy Aqueduct. It is 11 feet wide and 12 feet 9 inches tall, carrying water from the Ware River to Quabbin Reservoir or from Quabbin Reservoir to the Wachusett Reservoir, from which water is delivered to 41 metropolitan Boston communities.

The Chicopee Valley Aqueduct (CVA) carries water from Quabbin Reservoir to the Chicopee city line. Legislation authorized the construction of this aqueduct in 1947 and construction was completed by 1950. The CVA is 13.1 miles long and carries a diameter of 48 inches for 4.5 miles and 36 inches for 8.6 miles. The CVA delivers Quabbin water directly to Wilbraham, South Hadley Fire District #1, and Chicopee.

2.1.4.3 MWRA Water Treatment Facility for the Chicopee Valley Aqueduct

Water delivered to Wilbraham, South Hadley Fire District #1, and Chicopee is treated at the MWRA Water Treatment Plant in Ware, MA. This facility, which came on line in 2004, uses measured doses of chlorine to disinfect the water arriving from the Quabbin Reservoir, and adds chloramines to continue to protect the water as it is carried long distances via the CVA from the Reservoir to the receiving towns.

2.2 Quabbin Reservoir Watershed Ownership and Land Use

2.2.1 Current Land Uses

Among the most important aspects of the Quabbin Reservoir watershed for the protection of its waters as drinking supply is the nature of the land cover / land use of this watershed. As shown in **Table 9**, a full 93% of the watershed is in forest or wetland cover, and less than 5% of the watershed has been developed for agricultural, residential, or commercial / industrial purposes. Population density on the Quabbin watershed is fewer than 20 people per square mile, while the density on the Wachusett watershed, by contrast, is approaching 300 people per square mile.

Table 9: Land Cover, Land Use, and Population Density by Watershed

	Land Cover/Land Use (%) Excluding the Reservoirs							
Watershed	**Forest**	**Wetland**	**Agriculture**	**Residential**	**Commercial/Industrial**	**Open Water**	**Other**	**Persons per sq. mi.**
Quabbin Reservoir	87	6	3	1	0.1	0.3	3	16
Ware River	75	11	5	3	0.2	3	4	77
Wachusett Reservoir	67	8	8	9	0.6	2	7	284
Total	***77***	***8***	***5***	***4***	***0.3***	***2***	***4***	***109***

Source: (MDC, MWRA, and CDM, 1997)

2.2.2 Ownership

DCR owns the most sensitive lands within the 119,935 acre watershed of the Quabbin Reservoir, defined as the lands directly surrounding the reservoir and lands within 400 feet of tributaries to the reservoir. Including the 24,581 acre reservoir surface (21%) and 53,987 acres of watershed land (45%), DWSP presently controls 66% of the Quabbin Reservoir watershed (note that DCR/DWSP also controls 4,425 acres of land that are adjacent to but outside of the watershed boundary). Excluding the surface area of the full elevation reservoir, DWSP presently controls 57% of the land surface within the watershed. In addition, 17,163 acres (18% of the watershed land) is protected by other governmental agencies and private/non-profit groups (**Tables 10 - 12**).

Table 10: DCR/DWSP Land Holdings and Other Protected Watershed Lands

	Ownership as % of Watershed*		
DCR/DWSP Watershed	**DCR/DWSP -Owned**	**Other Protected****	**Total Protected**
Quabbin Reservoir	57	18	74
Ware River	38	20	57
Wachusett Reservoir***	29	26	52
Total	**43**	**21**	**64**

Source: (DCR/DWSP-GIS, 2003)
* Watershed area excluding reservoir surface.
** Includes lands owned by other state agencies, local government, and private entities; excludes Ch. 61 and Stewardship lands.
*** Includes 2,213 acres owned by DCR Division of State Parks and Recreation under a Care and Control MOU.

2.2.2.1 Public Lands

In addition to the 53,987 acres of land under DWSP control in the watershed, there are 8,207 acres under the care and control of other state agencies (5,395 acres - **Table 11)** and municipalities (2,812 acres). 2,381 acres are under the control of the DCR Division of State Parks and Recreation and the DCR Bureau of Forestry, primarily in the Shutesbury and Federated Women's Club State Forests, but also including portions of four other State Forests. The DFG Division of Fisheries and Wildlife controls 3,015 acres of land in the watershed, within six Wildlife Management Areas that intersect the watershed boundary.

Table 11: Public Agency Land Holdings within the Quabbin Reservoir Watershed

Agency/Areas	Acres
DCR DIVISION OF STATE PARKS AND RECREATION *DCR BUREAU OF FORESTRY*	
Federated Women's Club State Forest	936.0
Shutesbury State Forest	729.6
Wendell State Forest	535.7
New Salem State Forest	146.4
Petersham State Forest	32.8
Sub-Total	2,380.5

Agency/Areas	Acres
DFG – DIVISION OF FISHERIES AND WILDLIFE	
Philipston Wildlife Management Area	1,670.0
Popple Camp Wildlife Management Area (Petersham)	851.1
Raccoon Hill Wildlife Management Area (Barre)	286.8
Other Barre Wildlife Management Areas	81.5
Wendell Wildlife Management Area	73.3
Petersham Wildlife Management Area	52.1
Sub-Total	3,014.8
TOTAL	***5,395.3***

2.2.2.2 Private Lands

2.2.2.2.1 Protected Lands

Privately owned lands within the watershed that are currently protected from development include holdings owned by Harvard University, the Massachusetts Audubon Society, and the Trustees of Reservations. These holdings currently total approximately 17,200 acres.

2.2.2.2.2 Developed and Developable, Unprotected Lands

Less than 5% of the Quabbin Reservoir watershed is currently developed, with approximately 62,800 acres of the forests and wetlands either owned by DCR/DWSP for water supply protection or by other state agencies for a variety of functions. 24% of the watershed (28,846 acres) is privately owned forest land and could be developed in the future for residential, commercial, industrial or other land uses if permitted by zoning laws. The cumulative amount of development that is expected in the watersheds is much lower than the current amount of available "unprotected" land. The rate of development depends on many social and economic factors, including development pressure, the need or willingness of current owners to sell their land, and population growth. DCR also protects watershed lands from development through acquisition of conservation restrictions (CRs) and DCR currently holds approximately 716 acres of CRs in the Quabbin Reservoir watershed.

Table 12: Land Ownership within the Quabbin Reservoir Watershed

Owner	Land Acres	Reservoir Acres	Percent of Watershed	Percent of Watershed Area Excluding Quabbin Reservoir
DCR DWSP	53,987	24,581	66%	57%
Other Public	8,207	0	7%	9%
Private	32,833	0	27%	34%
TOTAL	**95,027**	**24,581**	**100%**	**100%**

2.3 Physical Characteristics of Quabbin Watershed Lands Under DWSP Control

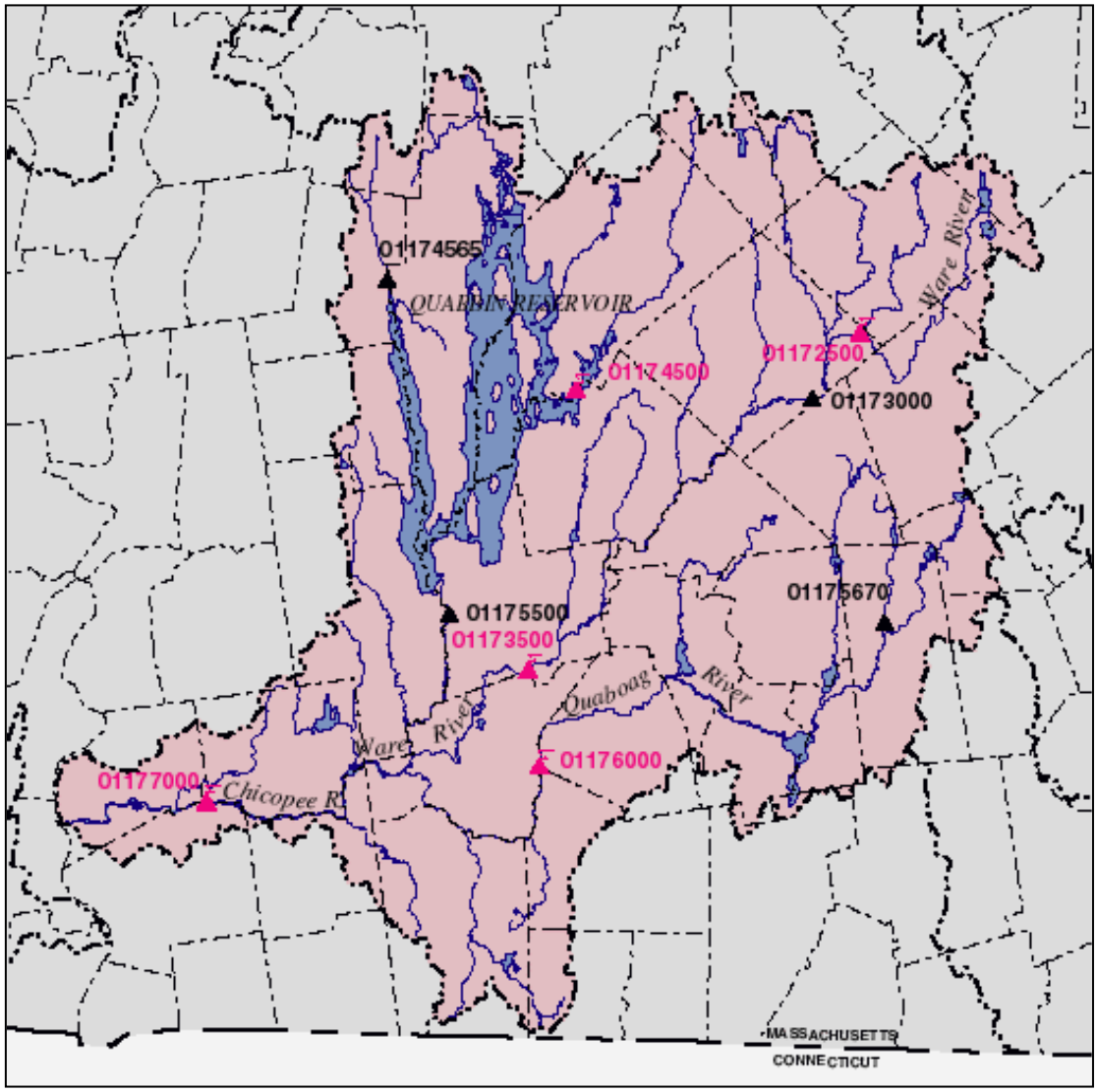
2.3.1 Watershed Delineation

The Quabbin Reservoir is situated within a hierarchy of basins, watersheds, and subwatersheds as described below and depicted in **Figures 4 - 8**.

2.3.1.1 Basin

The 721 square mile Chicopee River Basin includes the lands draining to four major river systems, the Swift River, the Ware River, the Quaboag River, and the Chicopee River (**Figure 4**).

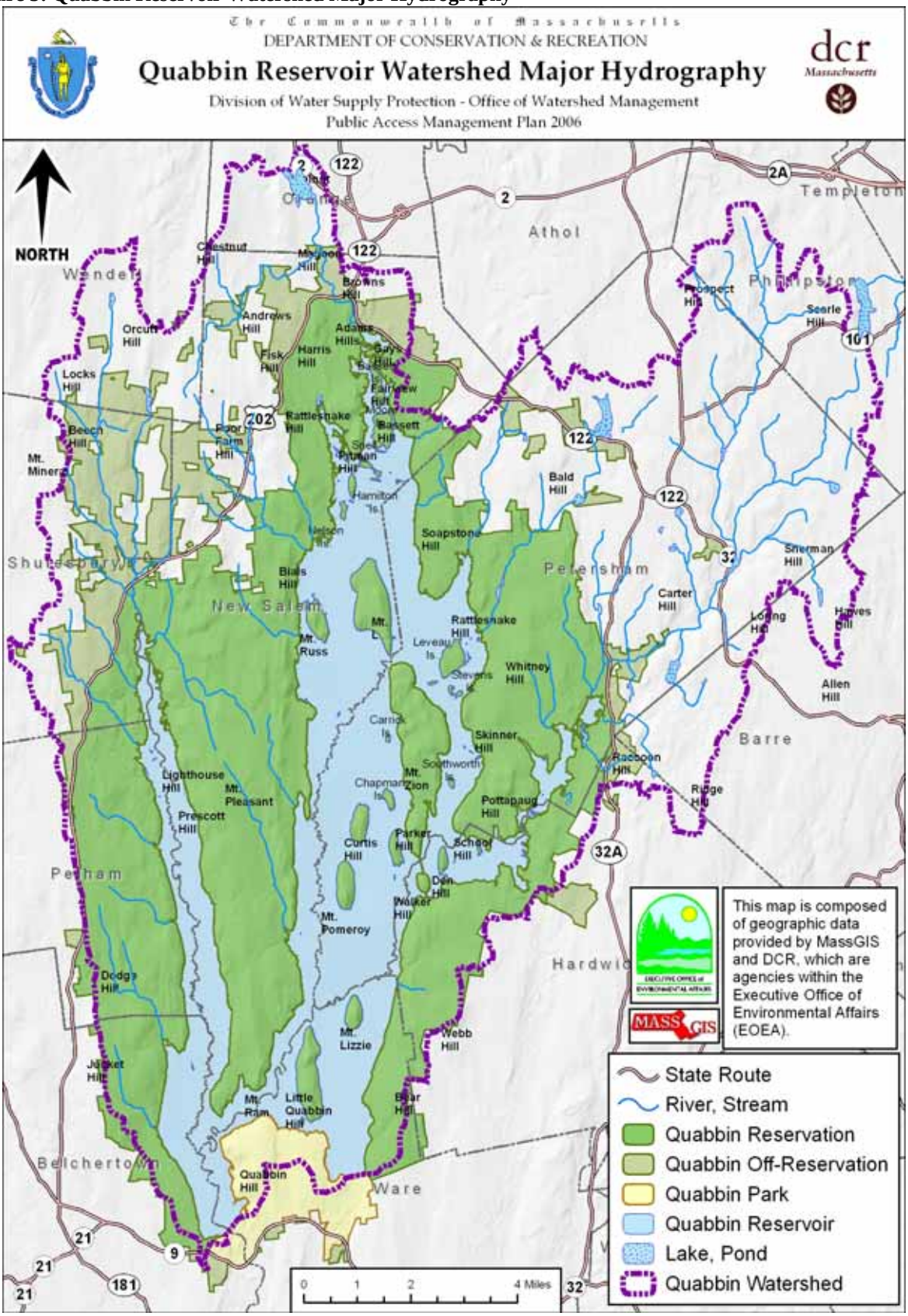
Figure 4: Chicopee River Drainage Basin and Quabbin Reservoir



2.3.1.2 Watershed

The 187 square mile watershed of the Quabbin Reservoir encompasses the lands and waters upstream from Winsor Dam, the terminal point of the reservoir. This reservoir and its watershed are also the major component of the watershed of the Swift River, which continues below the Quabbin Reservoir until the point at which it enters the Chicopee River. **Figure 5** shows the major hydrographic features of the Quabbin watershed.

Figure 5: Quabbin Reservoir Watershed Major Hydrography



2.3.1.3 Subwatersheds

59 subwatersheds have been identified within the Quabbin Reservoir watershed (**Figure 6)**, including the Cadwell Creek subwatershed depicted in **Figure 7**. These subwatersheds generally include the land and waters drained by tributaries from the point at which these enter the reservoir. Most of these are third order or higher tributaries.

Figure 6: Subwatersheds of Quabbin Reservoir Watershed

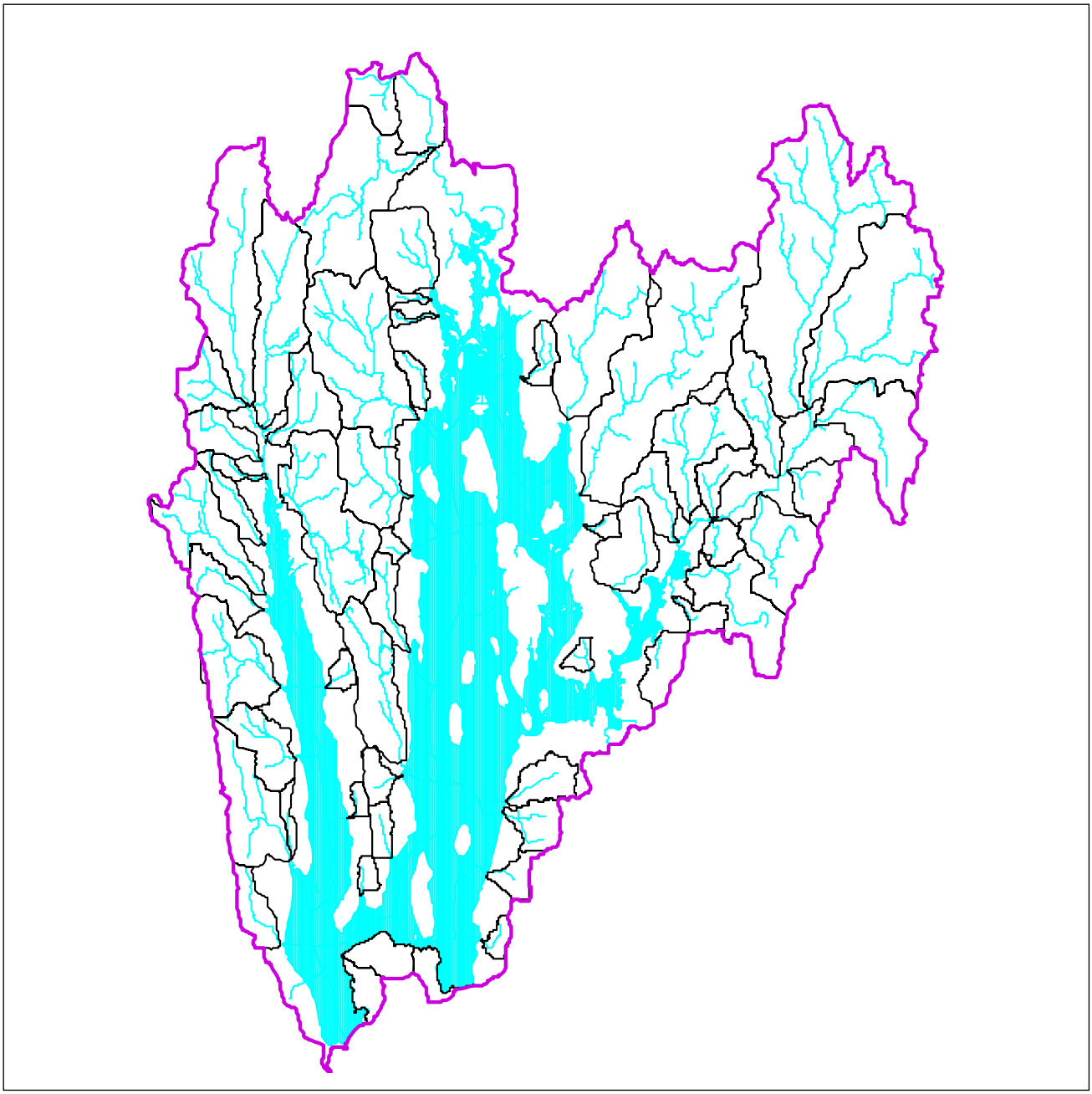
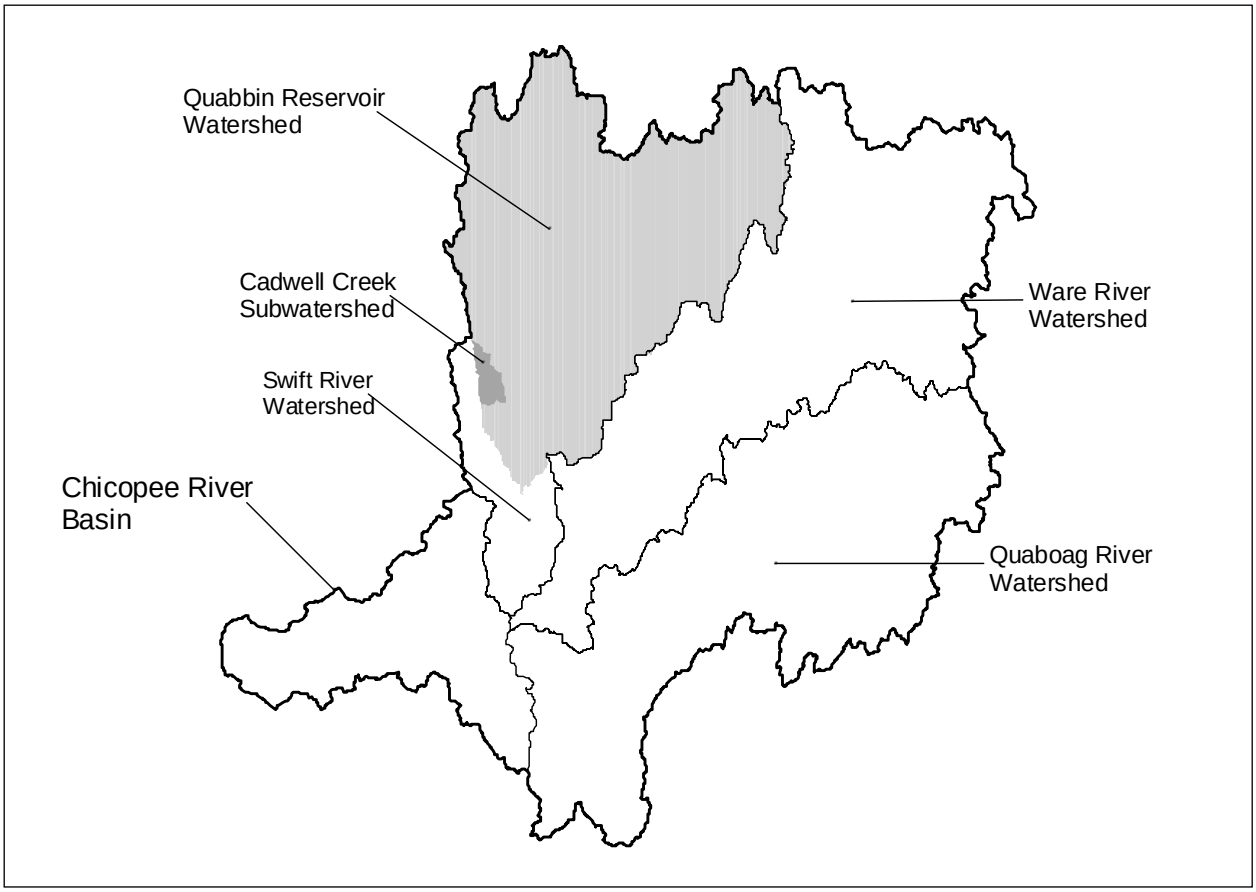


Figure 7: Quabbin Reservoir Watershed Hierarchy



2.3.1.4 Catchments

While catchments are not regularly used to guide management, they generally refer to areas that encompass the lands and waters that drain first or second order tributaries within the watershed.

2.3.2 Topography

The Quabbin Reservoir is located on the west flank of the eastern upland of south-central Massachusetts, an area characterized by extensive preglacial erosion and weathering followed by two major continental glaciations during the Pleistocene Epoch. The topography of the eastern part of the Quabbin watershed is irregular with moderate slopes, while the western part is characterized by two well defined, steeply sloped ranges oriented north and south through the length of the watershed. Elevation of the watershed ranges from 530 feet above mean sea level (reservoir's full pool elevation) to 1,383 feet above mean sea level, the elevation of Prospect Hill in Philipston, the tallest hill on the watershed. The topography is characterized by north and northeast trending hills and relatively narrow valley bottoms.

Excluding the reservoir surface, the land within the Quabbin Reservoir watershed falls within four broad slope classes, as detailed in **Table 13**.

Table 13: Acres of Quabbin Reservoir Watershed by Slope Class

Slope Class	Acreage	Percent of total
0-7.00%	34,270	36%
7.01-20.00%	48,123	51%
20.01-30.00%	8,760	9%
>30.00%	4,202	4%
TOTAL	**95,355**	

2.3.3 Geology

2.3.3.1 Regional Bedrock Geology

Note: this section was written by Peter Robinson, former Engineering Geologist for the MDC Water Division, for the 1986 MDC publication, "A Ten-Year Forest and Wildlife Management Plan for the Quabbin Watershed", pages 7-10.

The bedrock geology of the Quabbin Reservoir area is complicated, but in general, the rocks are complexly folded, medium to high-grade crystalline metamorphics in places intruded by granitic rocks. The rocks of the Quabbin region can be divided into four major groups.

1. The Pelham dome consists of a core of layered granitic gneisses with minor amounts of interbedded quartzite, schist, and amphibolite. In addition there are gray plagioclase gneisses similar to the Monson Gneiss around the margin rimming the core of the dome. The Pelham dome is located west of Quabbin. DCR/DWSP land holdings intersect the Pelham dome only in Pelham, Belchertown, and Shutesbury. The granite gneisses of the core are the oldest rocks in the area, on the order of 600 million years in age. The gray plagioclase gneisses are probably equivalent to the Monson Gneiss described below.
2. The Monson Gneiss is a gray, plagioclase-feldspar gneiss. It is variable, consisting of: a) layered gneiss without interbedded amphibolite; b) layered gneiss with interbedded amphibolite; c) massive (non-layered) gray gneiss; and d) minor amounts of other rocks. The layered gneiss may be of volcanic derivation whereas the massive portions may have been intrusive. The Monson Gneiss is of probably Early Ordovician age (450-500 million years ago). The Monson Gneiss underlies most of the low-lying land of the Swift River valley. The Monson Gneiss has been highly susceptible to erosion for reasons that are not fully understood. It is this erodibility that accounts for the broad expanse of the Swift River valley, a factor in its selection as a reservoir site. The rocks of the Pelham dome and the Monson Gneiss are now exposed in large dome-like structures, the tops of which have been truncated by erosion. These "domes" protrude up through the overlying rocks described immediately below.
3. The mantle sequence is so called because it structurally mantled the rocks of the Pelham dome and the Monson Gneiss prior to its removal from across the tops of the domes by erosion. The mantle sequence now occurs only where it has been preserved in the troughs between the domes. The mantle sequence consists of several formations, as follows:
    a. Ammonoosuc Volcanics – primarily layered volcanics of Middle Ordovician age (450 +/- million years ago).
    b. Partridge Formation – 430 to 450 million years ago consisting mostly of rusty-weathering sulfidic mica schist with interbedded amphibolites, also Middle Ordovician.

c. Fitch and Clough Formations – the Fitch Formation, of very minor occurrence, consists of calcareous granulites, traces of marble, and minor sulfidic schist. The Clough Formation consists of quartzite, stretched quartz pebble conglomerate, and minor schist. These formations are of Silurian age, 400 to 430 million years ago.

d. The Littleton Formation – mostly gray graphitic mica schist and minor quartzite of Early Devonian age, something less than 430 million years ago.

e. Erving Formation – mostly amphibolite and granulites, also of Early Devonian age.

4. Intrusive rocks of the region include the Hardwick Granite, the Belchertown Intrusive Complex, and the Prescott Complex. The Belchertown and Prescott complexes are more mafic than the Hardwick Granite, with a greater amount of iron and magnesium-bearing minerals, and also a feldspar content richer in calcium. This may affect the soil chemistry in these regions.

   a. The Hardwick Granite is a mass of granitic rocks of variable composition which range from granite to quartz diorite. The Kissman quartz non-zonite is also included. The rock contains distinctive large and elongate feldspar crystals.

   b. The Belchertown Intrusive Complex consists of massive biotite and/or hornblende quartz diorite and granodiorite. Only the very southwestern-most portion of the DCR/DWSP landholdings are on the Belchertown complex.

   c. The Prescott Complex occupying much of the Prescott Peninsula, is composed of gabbro, quartz diorite, and other related rocks.

The rocks at Quabbin have been affected by a series of tectonic events, the most recent of which occurred during the Acadian orogeny in the Early Devonian, about 380 million years ago. After initial folding of the rocks, the older and underlying gneiss now comprising the Pelham dome and the Monson Gneiss rose in huge bubble-like masses forming the gneiss domes. The overlying mantle sequence became draped over the rising gneisses and caught in the troughs between the domes. The intrusive rocks probably came in during this orogeny. Foliation in the intrusive rocks, however, suggests that intrusion occurred before the end of the orogenic events with the Hardwick Granite occurring somewhat earlier than the Belchertown and Prescott Complexes. Erosion subsequent to the orogenic events of the Early Devonian has removed thousands (perhaps as much as a few tens of thousands) of feet from the mountains formed at the time, now exposing the deep roots. Erosion, at its present level, has beveled the tops of the gneiss domes so that the mantle sequence is now preserved only in the downfolds between the domes. The domes are now surrounded by the mantle sequence rocks.

2.3.3.2 Surficial Geology

Much of the shape of the current Quabbin landscape was formed during the late Wisconsin glaciation when the Laurentide Ice Sheet spread south from Canada across New England approximately 25,000 years ago and then finally receded approximately 12,000 to 14,000 years ago (Whitney, 1994). The two-mile thick glacier impacted local topography and soils in a wide variety of ways, smoothing the landscape and leaving a cover of till, glaciofluvial deposits (material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice; these deposits are stratified and may occur in the form of outwash plains, deltas, kames, eskers, and kame terraces) and glaciolacustrine deposits (sand, silt and clay deposited on the bottom of huge temporary lakes that formed when melting glacial ice was blocked by a combination of underlying bedrock and deposits) (Whitney, 1994). Sand, silt and clay remain suspended in fast-moving river water, but in slow-moving water such as lakes these fine materials are deposited.

Most of the uplands in the Quabbin Reservoir watershed and Ware River watershed are covered with glacial till deposits several feet to tens of feet deep, although there are significant differences in deposits and topography in the Swift River versus the Fever Brook basins (Rittmaster and Shanley, 1995). Gravel till is the most extensive glacial deposit in the Quabbin Reservoir watershed. Lowlands and valleys are usually filled with stratified glaciofluvial outwash deposits of silt, sand and gravel, and occasionally with swamp deposits of muck and peat. Depth to bedrock is variable; bedrock outcrops are commonly observed on the top and sides of hills, but bedrock may also lie much deeper beneath surficial valley deposits.

2.3.4 Soils

Soils are an important functional component of the forest biofilter, and management on the Quabbin watershed protection forest works to promote, preserve and maintain soil quality and health. Soil quality is the capacity of a soil to function, and healthy soil is able to perform at least the following five essential functions (http://soils.usda.gov/sqi/concepts/concepts.html):

- Regulates water by holding, storing and releasing rainwater and snowmelt.
- Sustains plant and animal life and enhances biodiversity.
- Filters potential pollutants by immobilizing and detoxifying organic and inorganic materials.
- Cycles nutrients such as carbon, nitrogen and phosphorous.
- Supports structures such as roads, buildings and cultural resources.

For the purposes of watershed management, Quabbin soils have been grouped by depth and drainage characteristics into the following five classes, based on USDA NRCS soil series descriptions (**Table 14**). These groupings provide a general framework for management considerations such as site quality, species composition, equipment operability and BMP requirements, ensuring the maintenance of soil quality and sustained soil function. Specific capabilities and limitations for each soil series are detailed in the USDA NRCS Soil Survey.

1. **Excessively drained soils.** Excessively drained soils are usually very coarse textured, rocky or shallow. Water is removed from the soil very rapidly. These soils are thick loamy sands occurring primarily on glacial outwash. The principal soils occurring most frequently in these areas are the Hinckley, Merrimac, Windsor, Carver, and Suncook series. These are relatively deep soils (>65”) and occupy 80% of the excessively drained area. Inclusions* of the Deerfield and Sudbury series occupy the remaining 20% of the area and are located usually in the lower landscape positions. They are moderately well-drained fine sandy loams, usually very deep and very stony.

2. **Well drained thin soils.** These soils are commonly of medium texture. Water is removed from the soil fairly rapidly, but is available to plants during most of the growing season. The principal soils occurring in these areas are the Shapleigh series, which are shallow soils (1”-24”) formed in glacial till located on the sides and lower slopes of hills and ridges. The other major series is the Charlton-Hollis-Rock outcrop complex occurring in similar landscape positions. This complex consists of 45% deep Charlton soils, 10% shallow Hollis soils, 10% rock outcrops, and 35% other soils. These other soils, listed as inclusions, are Paxton soils, which are located on hills and knolls, Ridgebury and Woodbridge soils, which are located on the lower landscape positions, and Brookfield and Brimfield soils, which are located in the transition areas.

* Because of the scale used in mapping, small areas (generally less than 5 acres) are not shown separately on soil maps. These small areas are known as inclusions.

3. Well drained thick soils. These thick (24”-65”) soils are formed in loamy and sandy glacial till on uplands. The Canton, Gloucester, and Charlton series are found generally on the lower sides of hills and ridges. Various inclusions of Hollis, Ridgebury, Montauk, Woodbridge, Scituate, Essex, Paxton, and Brookfield series may be found at any given location. The Paxton, Essex, and Montauk series can generally be found on the tops and upper parts of hills and ridges. Inclusions of Brookfield, Canton, Brimfield, Charlton, Woodbridge, Ridgebury, Scituate, and Gloucester series may be found scattered throughout the upper portion of the landscape.

4. Moderately well drained soils. Moderately well drained soils are wet for only a short period during the growing season but the removal of water is somewhat slow during these times. These soils consist of very deep, (to 65” and greater) fine sandy loams. The Sudbury and Deerfield series are formed on outwash plains and terraces and occupy nearly level positions on the landscape. Other soil inclusions found within these types have been identified as the Merrimac, Walpole, Scarboro, Hinckley, and Windsor series. The Woodbridge series are formed on glacial till on uplands and are generally found on the tops of upper parts of hills and ridges. Inclusions of Charlton, Paxton, Canton, Montauk, and Ridgebury may occur within the Woodbridge series. The Scituate soil series, formed in glacial till on the uplands, is commonly found on the lower slopes of hills and ridges. Inclusions within this type are the Montauk, Canton, Woodbridge, Paxton, Ridgebury, and Walpole.

5. Poorly to very poorly drained soils. Poor drainage usually results from a high water table where water is removed so slowly that the soil is saturated or remains wet for long periods during the growing season. These soils are very deep, extending to a depth of 50” or more, and consist of fine sandy loams and mucks. The Ridgebury and Whitman series are found in depressions and in low areas on uplands. Inclusions of Woodbridge, Paxton, Scituate, and Swansea series comprise about 20% of these soils. Freetown and Swansea mucks are organic soils formed in depressions and on plain areas. These types can also contain about 20% included soils such as the Whitman, Scarboro, Ridgebury, and Walpole series. The Scarboro-Rippowam complex and the Walpole series occur in depressions and along drainage ways. The complex includes about 40% Scarboro, 30% Rippowam, and 30% other soils, while the Walpole has approximately 20% included soils from the Sudbury, Deerfield, and Swansea series.

Table 14: Acres of Composite Soil Type by Block[1]

Block	Excessively-Drained Soils	Well-Drained Thin Soils	Well-Drained Thick Soils	Moderately Well-Drained Soils	Poorly to Very Poorly-Drained Soils
Hardwick	1,548	4,017	3,469	2,283	837
Pelham	429	3,909	3,623	2,385	707
New Salem	2,334	2,705	3,609	1,145	1,186
Prescott	612	6,294	2,619	1,716	896
Petersham	862	2,374	2,065	3,620	972
Total	**5,785**	**19,299**	**15,385**	**11,149**	**4,598**
Percent of Watershed	10.3	34.3	27.4	19.8	8.1

[1]For management purposes, the Quabbin holdings are divided into 5 large regions or “blocks”, named after the local town

Generally, the soil within the Quabbin Reservoir watershed supports a wide variety of native tree species, most notably northern red oak, eastern white pine, red maple, sugar maple, and white ash. The dominant forest cover is oak with red maple occurring on the wetter sites and white pine dominating the drier sands and gravel (while white pine grows vigorously on moist soils, it competes poorly with other species on these sites during the establishment phase of the stand). Sugar maple and white ash are generally limited to less acidic soils with moderately high moisture content.

2.3.5 Hydrology and Climate

2.3.5.1 Precipitation and Evaporation

Annual precipitation on the Quabbin Reservoir watershed since 1930 has averaged 46.38 inches per year, with a range between a low of 29.7 inches in 1965 and a high of 66.4 inches in 1938 (**Table 15**). Historically (1930 to 1979), September has been the wettest month, with an average of 4.11 and a maximum of 14.8 inches of precipitation, while February has been the driest month, with an average of 2.97 inches. Of the 46 inches of precipitation that fall directly on the 24,000 acre Reservoir surface, approximately 22 inches evaporate. Annual evapotranspiration (water lost through the combined effects of evaporation from the ground surface and transpiration from the vegetation) in central Massachusetts has been estimated between 22 and 28 inches (Thornthwaite et al., 1958). The average yield to the Reservoir from the entire watershed is approximately 50% of all precipitation. The Reservoir, at full elevation of 530 feet, contains 412 billion gallons within a shoreline that totals 181 miles in length.

The hydrology of the watershed is strongly influenced by the preponderance of forest cover. Forest cover has both positive and negative effects on water yield, with net yield the result of precipitation, evapotranspiration, interception, soil moisture and ground water storage. Watershed studies show that evapotranspiration losses from forests are significant, but highly variable, with water yield increases occurring when part or all of a forest cover is removed or replaced by herbaceous vegetation. The most significant yield differences among forest covers are between conifers and deciduous trees. (Note that the current Quabbin forest is approximately 2/3 deciduous and 1/3 conifer, primarily pine.) In general, forest canopy interception and evapotranspirational losses are greater for conifers than for deciduous species, although this varies with stocking and with storm characteristics (deciduous forests average 13% overall interception losses, while coniferous forests average 28%, (Dunne and Leopold 1978). The creation and maintenance of open land generally reduces interception and evapotranspiration losses and can result in a significant increase in yield.

2.3.5.2 Snow surveys

The Division has conducted a snow survey in the Quabbin Reservoir watershed since the 1930s. The purpose of the survey is to record the potential rise in reservoir elevation (potential inflow) as well as the flood potential of rivers and streams due to snowmelt. Prior to the filling of the Quabbin Reservoir, the Division monitored twelve snow survey stations in the Quabbin Reservoir watershed. Once the reservoir was filled, six of the twelve stations remained. DWSP staff currently monitors six snow survey stations weekly, typically between January and April, taking six samples at each station using a snow density gage to measure snow depth and weight. The average depth and weight measurements are used to determine the average water content of the snow pack. Staff report average depth and water conversion figures as both “potential rise in reservoir elevation” and as “river and stream flood potential”. Over the past 22 years, the average annual snow depth at the six stations within the Quabbin Reservoir watershed has been 47.47 inches.

Table 15: Total Annual Precipitation Measured at Belchertown Station

Year	Annual Total Precipitation		Year	Annual Total Precipitation
1930	39.36”		1969	44.58
1931	45.30		1970	41.95
1932	41.43		1971	44.58
1933	53.48		1972	57.88
1934	49.64		1973	50.24
1935	38.15		1974	49.43
1936	55.24		1975	58.98
1937	55.71		1976	46.19
1938	66.41 **(max.)**		1977	52.01
1939	38.37		1978	43.55
1940	40.48		1979	58.59
1941	32.66		1980	32.41
1942	47.55		1981	42.99
1943	43.99		1982	48.09
1944	42.40		1983	57.41
1945	50.71		1984	49.92
1946	38.43		1985	45.93
1947	39.42		1986	44.2
1948	45.25		1987	40.38
1949	37.40		1988	43.42
1950	41.30		1989	58.02
1951	49.73		1990	53.10
1952	45.19		1991	51.72
1953	51.52		1992	41.63
1954	49.03		1993	43.5
1955	64.92		1994	50.85
1956	46.57		1995	44.98
1957	36.32		1996	60.43
1958	49.47		1997	43.8
1959	54.25		1998	43.38
1960	50.57		1999	48.11
1961	41.75		2000	52.97
1962	38.14		2001	39.87
1963	41.64		2002	44.36
1964	31.57		2003	54.03
1965	29.7 **(min.)**		2004	42.15
1966	36.66”		2005	54.38
1967	44.89		2006	44.18
1968	40.47		**Average**	**46.35**

2.3.5.3 Streamflow

The Quabbin Reservoir drains a land area totaling approximately 150 square miles (~96,000 acres). In order of size, the most important subwatershed drainages include the East Branch of the Swift River (43.7 sq.mi.), the West Branch of the Swift River (12.4 sq.mi.), the Middle Branch of the Swift River (10.7 sq.mi.), the East Branch of Fever Brook (8.7 sq.mi.), Hop Brook (5.4 sq.mi.), the West Branch of Fever Brook (4.5 sq.mi.), and Dickey Brook (4.3 sq.mi.) (**Figure 6**). The Ware River watershed, upstream from Shaft 8, is a major tributary to the Reservoir during high flow winter periods when diversion may occur. Within the portion of the watershed owned by DCR, there are approximately 132 miles of streams, excluding intermittent streams, and 2,272 acres of wetlands, including year-round water bodies, but excluding vernal pools.

Stream flow in the Quabbin Reservoir watershed, as in most of New England, has significant seasonal variations. Flows tend to be highest in the spring, due to snowmelt and high groundwater; and lower in the summer and early fall due to greater solar radiation and evapotranspiration. These seasonal changes are important since "high flow" water quality threats (e.g., streambank erosion) tend to occur in the spring, whereas "low flow" water quality threats (e.g., higher bacteria levels resulting from lower dilution) tend to occur in the summer and early fall. DCR staff monitors stream flow at selected sites where Quabbin water quality samples are taken. Sample data on stream flow are shown in **Table 16.**

Table 16: Streamflow Data for Selected Tributaries of the Quabbin Reservoir

Station Name (number)	1996 Data (cfs = cubic feet per second)				
	Drainage Area (miles^2)	Mean Daily Discharge Rate (cfs)	Maximum Daily Discharge Rate (cfs)	Minimum Daily Discharge Rate (cfs)	Total Annual Discharge
East Branch Swift River Near Hardwick, MA (01174500)	43.7	135	985	9.8	4.3 billion cf (31.8 billion gals)
West Branch Swift River Near Shutesbury, MA (01174565)	12.6	37.5	377	1.2	1.2 billion cf (8.8 billion gals)
Cadwell Creek Near Belchertown, MA (01174900)	2.55	8.86	80	0.21	0.3 billion cf (2.1 billion gals)

Source: USGS-MA, 2000

2.3.6 Developed DWSP Lands at Quabbin

2.3.6.1 Administrative Areas

2.3.6.1.1 Administrative Buildings

The Quabbin Administration Building, located in Quabbin Park, was built between 1938 and 1939. The Visitor Center and many of the professional staff offices and meeting areas are located in this building. The Quabbin Visitor Center was opened in 1984 to meet the growing demand for visitor information services (surveys have recorded in excess of 500,000 visitors annually). The Quabbin Administration Building also houses State Police offices and the separate garages used for storage and mechanical maintenance/repair. The historic seaplane hanger beneath the Administration Building houses equipment and carpentry and sign-painting shops. There are also a Forestry/Natural Resources office and the

Ranger's Headquarters in the Quabbin Park, as well as a stock room for tools, supplies and an adjacent welding and metalworking shop. In addition to the administrative buildings at the southern end of the Reservoir, there is a Forestry field office and a heavy equipment garage complex at the northern end, off Route 202 in North New Salem.

2.3.6.1.2 Quabbin Hill Lookout Tower

The Quabbin Hill Lookout Tower was built from 1940-1941. The tower is 84 feet high. On a clear day, in addition to the Reservoir itself, a visitor can see portions of Massachusetts, New Hampshire, and Connecticut from the tower.

2.3.6.2 Boat Launch Sites

There are three boat launch sites on the Reservoir for boat fishing in designated areas: Area 1: Gate 8 off Route 202 in Pelham; Area 2: Gate 31 off Route 122 in New Salem; and Area 3: Gate 43 off Route 32A in Hardwick, MA. These areas include field offices for staff, parking areas for vehicles and boat trailers, launching docks, and sanitary facilities.

2.3.6.3 Powerline Rights of Way

Powerline rights-of-way cover 289 acres within DWSP holdings surrounding Quabbin Reservoir and include three major lines:

1. An overhead powerline entering DWSP property near Gate 9 in Pelham and running SE to and then parallel to the shoreline toward the DWSP Administration Building in Quabbin Park (E5/F6 line), then easterly through the Park, exiting just beyond Peppers Mill Pond (B-69 line).
2. An underground cable line that crosses DWSP boundaries several times within the towns of Shutesbury and New Salem, running northeasterly and crossing Route 202 into the Quabbin Reservation north of Giles Brook, then leaving DWSP property north of North Spectacle Pond.
3. An overhead powerline that enters DWSP property in New Salem, north of Gate 28, runs southeasterly across the northern tip of the Reservoir, through DWSP properties in Petersham, and then leaves DWSP property between Gate 40 and Carter Pond, in Petersham (E205E line).

2.3.6.4 Quabbin Park Cemetery

The Quabbin Park Cemetery was built between 1931 and 1932. During that time, 6,601 remains were transferred. The Cemetery is 82 acres in total size, including 22 developed acres.

2.3.6.5 Fields and Other Non-Forest Areas

There are 88 acres of lawns and ornamental plantings at Quabbin, as well as 154 acres of administrative areas, 311 acres of fields with grass and herbaceous cover, 111 acres of upland brush, 8 acres of abandoned orchards, and approximately 20 acres of active gravel pits.

2.4 Quabbin Forest Conditions

2.4.1 Forest History

2.4.1.1 Paleoenvironments

The following is quoted from a September 1990 report by the Cultural Resource Group of Louis Berger & Associates, Inc. It is included here for general information on post-glacial development of the landscape, and to provide a context for prehistoric cultural resources protection.

> Prior to prehistoric man's entry into central Massachusetts, glaciers had scoured the landscape. Glacial Lake Nashua occupied the approximate position of the Wachusett Reservoir and another, Lake Hitchcock, was located from 10 to 15 miles west of Quabbin. The lakes were apparently gone or recently drained as prehistoric Native Americans began to populate the area.
>
> Forests of this early time are characterized as spruce parkland and spruce woodland with admixtures of some deciduous elements creating a species mosaic that has no modern analog (Curran and Dincauze 1977). Excessively drained glacial landforms would have been attractive to both man and animal during this time of cooler and wetter climate. The biological carrying capacity of area forests would have been less than that of modern habitats in the same area but greater than what can be ascribed to modern conifer-dominated forests.
>
> Bogs, marshes, and ponds probably characterized many lowland environments as they do today. The effects of beaver populations on these lowland environments during prehistoric times cannot be accurately evaluated. Beaver are responsible for many of the modern wetland features. The types of vegetation associated with them, however, would have been substantially different. Nonetheless, we can assume that these features would have been game-attracting habitats. Extinct and more northern-adapted animal species would have existed in the area including mastodon and caribou. Now-extinct drainage patterns were probably viable low order streams. The velocity of streams in general was probably great as they handled glacial meltwater.
>
> As regional climates began warming circa 8,000 BC, the spruce woodland was eventually replaced by a conifer-deciduous forest in which pine was heavily represented (Dincauze and Mulholland 1977). No dramatic changes in the biological carrying capacity of the project region are postulated although northern animal species were likely being supplanted by species more common to the area today. Streams were undoubtedly prolific, even in comparison with the well-watered settings of the present time.
>
> Climates circa 6,000 BC and 1,000 BC are viewed as radically oscillating with warm temperatures and decreased rainfall being the overall trend. Windblown soils found in Central Massachusetts and the Middle Connecticut River Valley (Johnson and Stachiw 1985; Johnson and Mahlstedt 1984; Dincauze et al., 1976) may be an indirect result of this period referred to as the Thermal Maximum. Pine-oak forests give way by 4,000 BC to a temperate deciduous forest characterized by oak and hemlock. These new plant communities, together with adapted animal species, would have dramatically increased the carrying capacity of local environments and the range and density of resources that could be exploited by humans.

Although many upland and low order streams may have become intermittent or extinct at this time, the quality of upland and lowland environments was dramatically increased. Seasonal changes were probably first pronounced during this period in terms of the fluctuating productivity of biological resources exploited by man. At the same time, decreasing rates of sea level rise would have helped to stabilize anadromous fish populations and regularize their appearance in local areas. Climatic shifts circa 1,000 BC and later are viewed as minor and resulted in no major alterations of regional environments. The quality of environments in Division watershed areas was essentially modern by 1,000 BC if not earlier.

2.4.1.2 Land Use and Disturbance History

The current New England forest carries the imprint of changes ranging from major climatic shifts thousands of years ago to the abandonment (and successional reclamation) of agricultural land within the past 150 years. The relative role of the range of disturbances visiting this forest has long been the subject of heated debate. Following is a brief review of some components of this debate.

2.4.1.2.1 Prior to European Settlement

There is considerable uncertainty as to what the actual pre-colonial forest was like in the Quabbin region. Overall species composition in this early New England forest was likely similar to the present day with the exception of species since extirpated, like chestnut, or imported from other areas, like red pine. The distribution of size-classes of the pre-colonial forest would have been influenced greatly by the length of time since the last major weather disturbance, especially hurricanes, and the severity and magnitude of previous fires or of Native American land use practices. Hurricanes disturb New England frequently, with catastrophic storms arriving, on average, every 100-150 years. Fires occurred naturally in the pre-colonial forest, but may have also been set by the Native American populations for a variety of reasons, including facilitation of hunting and clearing for agriculture.

Bromley (1935) and Day (1953) felt that the population of Native Americans in pre-Colonial times was sufficient to burn large areas of forest frequently and that burning was a universal custom to keep forests open and to produce browse for wildlife. Bromley also points out that in some cases deer modified the forest locally. He notes that larger trees occurred mainly in wetter woods, and that oak and pine forests were usually subjected to annual burnings, while beech and maple were commonly too wet to burn. The prevalence of oak in the original forest is likely in part due to the long history of regular but infrequent fire (Bromley (1935) and Russell (1983)). Some ecologists feel the impact of fires was great enough to have increased the oak-chestnut forest type significantly and effectively caused it to replace the northern hardwoods forest in interior sections of New England.

The fact that turkey, deer, and ruffed grouse flourished indicates an environment with edge. The decline of quail, which occurred in pre-settlement times, also indicates that regrowth of forest and fire suppression in modern times negatively impacted some species (Thompson and Smith, 1970). Thompson and Smith (1970) suggest that the demise of the heath hen (which disappeared from Massachusetts in 1840) was probably due to fire suppression after settlement, and that, in general, fire has been a key factor in the past abundance and distribution of New England wildlife.

Whatever their cause, disturbances likely maintained a diversity of ages, sizes, and species in the early Quabbin forest. While stands of mature, mid to late successional species of great size are in the historical record, the pre-colonial Quabbin landscape was likely a patchwork of varying composition, given the record of disturbance (Cronon, 1983). However, this mosaic, wrought by a variety of randomly patterned disturbances, was forced into a simpler pattern by the arrival of the colonists, a population bent on agricultural development.

2.4.1.2.2 Colonial Settlement

By the close of the 18th century, colonists had eliminated almost all of the "original" New England forest (Carroll, 1973). At the peak of colonial development around 1850, greater than 75% of the Massachusetts forest had been cleared (Russell, 1976, p.527), leaving only the steep and rocky sites and wetlands in tree cover. Land had been initially cleared for general agriculture, followed by a large expansion of clearings to support the rearing of sheep. The forest supplied building material for homes and barns, fuel for cooking and heating, charcoal, and other forest products that provided income. Excess wood was simply piled and burned to complete agricultural clearings.

Although the task of clearing the original forest with hand tools was formidable, it pales in comparison with the energy expended to wrestle stone from the ground and use it to build fences and foundations. To link the fields and farms of this era, the roads followed the topography and consequently are often narrow, winding and steep. Gravel was not used in abundance for road surfaces and when additional fill was required it was usually dug from roadside banks.

The clearing of land for agriculture was to some extent ordered by a perception of soil/tree cover relationships:

> Trees that required and maintained moist forest conditions, such as hickories, maples, ashes, and beeches, generally produced rich black humus beneath their fallen leaves, and settlers interpreted them as indicators of prime agricultural land. Oaks and chestnuts, with their denser undergrowth and more frequent groundfires, had thinner soils which required more work before they would produce favorable European crops. Still less desirable were the acidic and often sandy soils beneath various conifers - moist under hemlocks and spruces, dry under pitch and white pines - and colonial farmers avoided these wherever they could. (Cronon, 1983)

While these observations may have directed the colonists to first clear the most productive soils, ultimately 75% of the central New England forest was cleared for some type of agriculture (Marchand, 1987). In addition, the colonists took advantage of rich wetland soils by ditching and draining them and using these moist soils for hay, cranberries and in some cases for crops (Russell, 1976).

2.4.1.2.3 Agricultural Abandonment

As more and better land was open for settlement further west and as New England's hill farms became unproductive, marginal agricultural lands were abandoned. During the period between 1830 and 1865 farm land abandonment in New England occurred at an unprecedented pace, exacerbated by the Civil War's recruitment of young farmers from the region and by industrialization (Marchand, 1987). For example, the Town of Petersham was estimated to be 15% forested in 1865, 48% in 1895, 55% in 1905 and 85% in 1976 (Patric and Gould, 1976). The Quabbin forest, which was likely also as much as 75% cleared land during the height of colonial agricultural development, would ultimately return to nearly 100% forest cover within 100 years time.

Much of this abandoned farmland would not be reclaimed by the same species composition which fills holes in a disturbed forest. Many of the abandoned fields had last been used either as pasture or to produce dwindling yields of hay, and so were in dense grass cover at the point of abandonment. This fact accounts for the emergence of white pine as a dominant forest type during the successional reclamation of these abandoned farms (Marchand, 1987). White pine and other conifers such as red cedar are better able to invade and repopulate these grasslands than other species because their heavy seed can penetrate grass to make contact with the soil and their drought tolerance enables them to survive dry summers, even with competition from dense grass roots for available moisture. Fields that were tilled right up to the time of their

abandonment would have immediately supported a broader range of early-successional species than those that were grasslands at the time of abandonment.

Early in the 20th century, as the white pine crop grew to merchantable size, the value of the standing pine trees increased dramatically (Marchand, 1987). A lumber boom, aided by the steam- powered portable sawmill, resulted in the logging of 15 billion board feet of primarily white pine lumber from the central New England region between 1895 and 1925. The trees were cut by hand, drawn out of the forest by horse, mule or oxen, and milled on site. The sawn lumber was used for boxes, buckets, matches and building materials. This market could use a variety of lumber grades and therefore both high and low quality stands were in demand.

The heavy cutting of white pine at the turn of the century favored regeneration by understory species that had established a tap root and thus could sprout vigorously after a disturbance, such as the oaks, hickories and chestnuts (Marchand, 1987). Most other species were less likely to persist following the intense logging activity and by the fires that followed in the dry slash of the old-field pine cutting. White birch seeded in after fire and became a component along with other birches and maples, but oaks eventually dominated the shorter-lived birches and maples. Similar to the conditions that preceded the establishment of white pine on abandoned farms, the heavy cutting and burning that established Quabbin's large, contiguous oak stands is not likely to be repeated.

2.4.1.2.4 Chestnut Blight

American Chestnut was a valuable and abundant hardwood tree in this region. This fast growing tree was normally associated with oaks and hickories. Chestnuts produced frequent seed crops that were important to both humans (food and cash crop) and animals. The trees grew tall with straight grain and therefore worked and split well. The wood was valued for barn and house frames, furniture, doors, fence posts, railroad ties (due to its rot resistance) and many other uses.

The chestnut blight (*Endothia parasitica*) was introduced around 1904 and within two decades had killed most of the mature chestnut trees in New England (Spurr and Barnes, 1980, p.450). Chestnut had occupied a wide variety of sites and was a significant component of the forest. Because chestnut had so many uses and decayed slowly, most of the mortality was salvaged through extensive logging operations. The blight caused a thinning where chestnut was a major component and stimulated the growth of residual trees. As succession reclaimed the openings left by the dying chestnut, it was often simply replaced by its common associates in the stand and the oak-chestnut types were simplified to oak-hickory or oak types (Spurr and Barnes, 1980, p.450).

The full impact on the forest ecosystem from the loss of chestnut is difficult to determine because it influenced so much of that ecosystem. Clearly, it had been an important food supply for wildlife (as well as humans), a major component of the forest affecting both structural and species diversity, and a persistent competitor for light and space in the regenerative phase of forest development. The growth and development of the next forest has been different because of this loss. There is some hope that chestnut will make a comeback when the disease weakens or the tree becomes more resistant. Researchers are currently working to splice genetic codes that will build resistance in the American chestnut, providing perhaps the best hope for the return of this tree to its native woodlands. For more information, contact the American Chestnut Foundation at: http://www.acf.org .

2.4.1.2.5 The Hurricane of 1938

The Hurricane of 1938 was a 100-150 year event that seriously damaged approximately 15,000 acres of the Quabbin forest, primarily on the east, southeast and south aspects. Level sites, northeast aspects and the upper slopes of north and northwest aspects were also damaged, though less severely. Across the watershed, the impact varied tremendously from nearly complete damage in older pine stands, to scattered individuals in young hardwood stands. Trees downed or tipped by this storm are still evident in present day stands. Pine rots slowly and in some areas of blow down, it is still difficult to walk through hurricane-affected stands.

Aftermath of the 1938 Hurricane.

A great effort was made to salvage the blow-down and several million board feet of the most accessible and best quality timber were salvaged by the MDC on Quabbin lands. Approximately 20 million board feet of mature timber, primarily white pine, were tipped, snapped, or felled by the hurricane. Even though large crews were sent into the woods to lop damaged trees, the pine remained a potential fire hazard for many years. Fortunately, much of the Quabbin watershed in 1938 was in 10-40 year old hardwood tree cover from turn of the century farm abandonment or recently planted seedlings on open land purchased by MDC, so these areas were not seriously damaged by the hurricane.

1938 was reported to have been a heavy white pine seed year. The hurricane spread this seed great distances and many young pine seedlings became established in the understory on well-drained uplands. Other good pine sites, such as the kame terraces, also regenerated to white pine following damage to the pine overstory. Mature pine stands on moist till soils regenerated to oak, ash, maple, birch, hemlock and scattered pine following the hurricane, whereas immature stands without advance regeneration regenerated to light-seeded hardwood species such as birch and maple.

2.4.1.2.6 Gypsy Moth

The gypsy moth was introduced in Massachusetts in 1869, as a potential silk producer. This local introduction of a non-native insect has had a significant impact on the Quabbin forest because these insects prefer the leaves of oaks, the most common hardwood species on the watershed. The dominance of oak in this region has enabled gypsy moth caterpillars to defoliate significant areas of the DWSP properties during peak infestations, especially on drier hilltops. From these hill tops young caterpillars can be blown for many miles and result in widespread defoliation. Mortality from the gypsy moth extends beyond the canopy red oak to a developing understory of pine, the less vigorous white, black and chestnut oaks and the scattered hemlocks within oak forests. Serious defoliations

Adult Gypsy Moth.

have occurred in 1889, 1964, and 1981. The most recent defoliation of any size affected the majority of the Mount Pomeroy Island in 2000.

Chemicals have not successfully controlled gypsy moths defoliations in New England. More effective natural control is usually caused by a nucleopolyhedrosis virus (*Borralinivirus reprimens)* brought on through starvation in the later stages of defoliation in the second or third year of the cycle and by a fungus that was released approximately 70 years ago to control gypsy moths (*Entomophaga maimaiga*), which has now increased to levels that are devastating the caterpillars in early stages of their development, so long as certain humid conditions are present. Effective long-term control may also result from the diversification of the oak forest, especially on the well-drained upland sites.

The introduction of the gypsy moth has affected the growth and composition of the Quabbin forest. Mortality rates have been high in oaks and mixed-stand hemlocks in outbreak areas, and growth rates are greatly diminished during the years of defoliation for trees that survive. Advance understory regeneration of pine has been killed, representing many years of growth. Particularly susceptible trees such as white oak have been lost from large areas of mixed oak forest. It is unclear what the future of this impact will be, although it will likely depend to a large extent on the ability of natural defenses, perhaps including changes in species composition, to adapt to the presence of the gypsy moth. In areas where mortality from gypsy moth has been or will be significant, the importance of maintaining the regenerative capacity of the forest cannot be overemphasized.

2.4.1.2.7 Elimination of Access

Once gates and signs were put up around the Quabbin Reservoir in the 1940s, the public was initially denied further access. Prior to this time the public had used the Quabbin lands for fishing, hunting and trapping. The concurrent impacts from clearing 24,000 acres, burning several thousand acres, and blow-down by the hurricane of 1938 on 15,000 acres produced large amounts of deer browse. Coupled with hunting prohibition, this resulted in a large deer population that seriously impacted the forest understory from the 1940s until hunting resumed, following long and contentious debate, in 1991.

The only exception to prohibited public access in the late 1940s was for shore fishing. A strong sportsmen's lobby prevailed over MDC's official objections to the program. Once walking access was allowed for fishing (1946), public access for hiking gradually gained acceptance for all but the Prescott Peninsula, which remains reserved for research and management purposes. In recent years, as open spaces throughout Massachusetts become increasingly developed, the demand for recreational use of the DWSP watershed properties has increased and will likely continue to provide management challenges into the future.

2.4.1.2.8 Public Access Management Plans

The first Public Access Plan for the Quabbin Reservoir watershed was published in 1988. This plan outlined control policies and monitoring mechanisms used to mitigate possible negative impacts from public access to Watershed Management property in Barre, Belchertown, Hardwick, New Salem, Orange, Pelham, Petersham, Shutesbury, Ware, and Wendell. An update was completed ten years later in 1998. Another update was initiated in 2005, and was completed in spring 2006.

DCR and its predecessor have continuously involved stakeholders in its public access policy development, review, and modification. The planning process for this latest update included two public meetings, a visitor survey, an abutter's survey, and a public hearing. DCR continuously receives pressure to allow new recreational opportunities and increase the availability of currently allowed activities. The input received while updating the Quabbin Access Management Plan demonstrated, however, that local

residents, land abutters, visitors, and environmental organizations are supportive of DCR's policies to protect the public water supply while allowing controlled access to these resources. **Figure 8** and **Table 17** provide a summary of the policies described in the 2006 *Public Access Management Plan Update: Quabbin Reservoir Watershed System.*

2.4.1.2.9 Primary Versus Secondary Forests

The vast majority of the current forest at Quabbin and across New England is the result of the return of the forest to lands that were cleared for agriculture following European settlement of the region. These forests are commonly referred to as 'secondary forests' or 'second growth'. However, over the course of post-settlement history, some woodlands within the region were not cleared to make way for agriculture. Primary forests, also referred to as "primitive woodlands" are areas that have, to the best of our knowledge, always been woods, and were never plowed or converted to pasture or hayfield. Henry David Thoreau discussed the concept of primitive woodlands as part of an overall forest classification system. Thoreau defined primitive woodlands as those that have always been forested, even though they may have been cut one or more times in the past to produce wood products. They are not to be confused with old growth, which are generally areas in which direct human manipulation has been mostly absent throughout history. The critical characteristic is that these woodlots were never used for agricultural purposes and that they therefore have always had a forest floor (Foster, D.R. 1999). There is increasing interest in these areas as reference areas for comparison to areas that were farmed, in an attempt to quantify the legacy effects of agriculture on soil and vegetation characteristics.

In an effort to identify primary forests, the Harvard Forest has gathered land use maps from 1830 that were produced by many towns in Massachusetts for tax purposes, and which identify woodlands present at that time. The assumption is that if an area had not been cleared for agriculture by 1830, it is likely that it was never cleared for this purpose as farm abandonment began in earnest shortly after this date. Landscape position also predicts these areas to the extent that very steep or very wet areas were not converted to agriculture. From these sites and using the 1830s maps, DWSP has identified areas totaling approximately 1,000 acres as potential primary woodlands. Through field checking, some of these potential areas have been removed from the designation because they were found to be bounded by stone walls, indicating that they were converted to agricultural uses at some point in the past.

Figure 8: Quabbin Reservoir Watershed Public Access Map

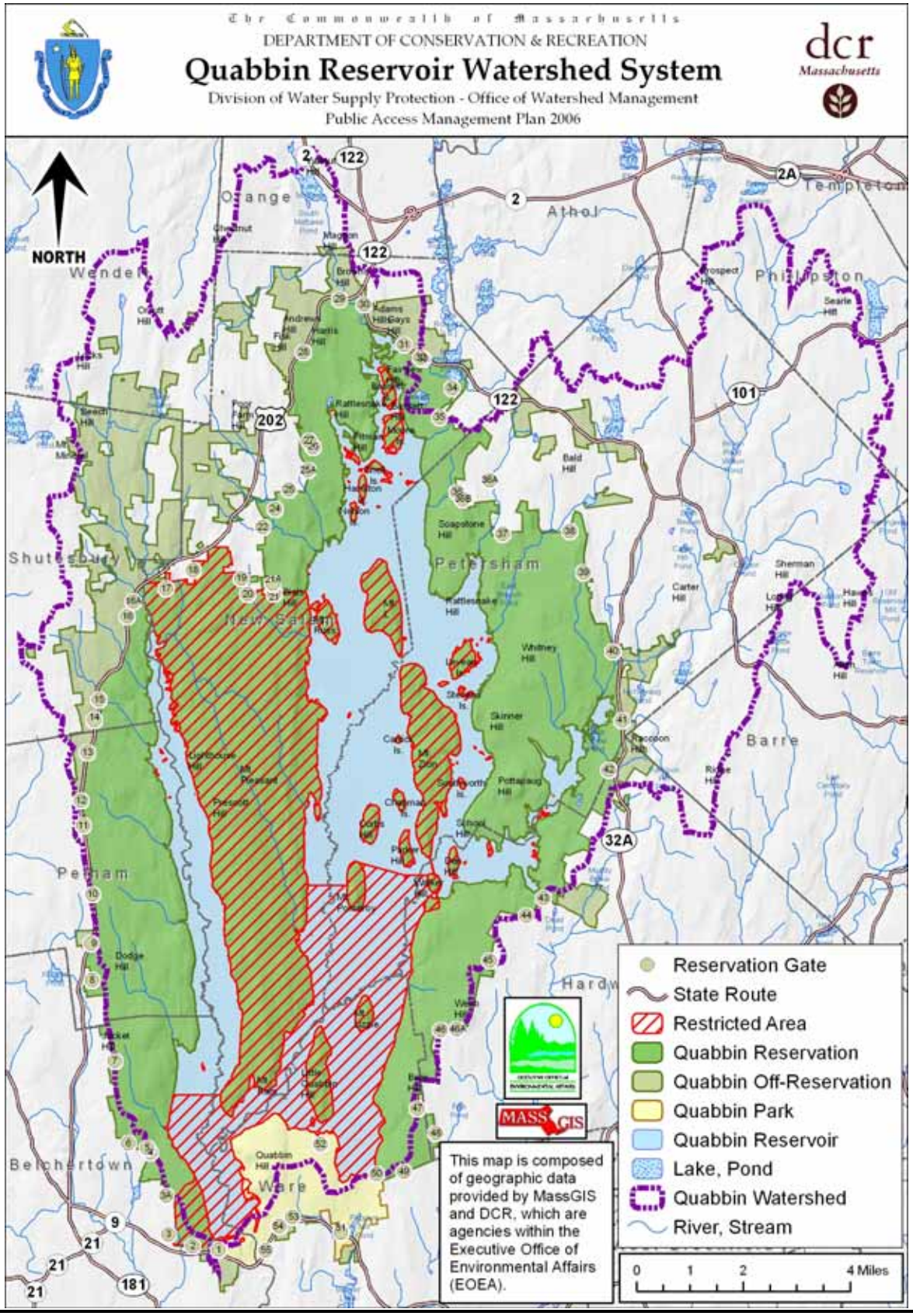


Table 17: Quabbin Reservoir Watershed Public Access Rules Summary

Activity	Quabbin Park	Quabbin Reservation	Off-Reservation	Quabbin Reservoir	Regulating Ponds[a]	Off-Watershed Ponds[b]
VEHICLE ACCESS						
Driving for Sightseeing	□ 1	Ò	Ò	Ò	Ò	Ò
Snowmobiling	Ò	Ò	□ 2	Ò	Ò	Ò
ATV Riding	Ò	Ò	Ò	Ò	Ò	Ò
Bicycling -Designated Roads	□ 3	□ 4	□ 5	Ò	Ò	Ò
Off-road Bicycling	Ò	Ò	Ò	Ò	Ò	Ò
Sledding	□ 6	□	□	Ò	Ò	□
FOOT ACCESS						
Walking/Hiking/Snowshoeing	□ 7	□ 7	□	Ò	Ò	□
Cross-country Skiing	Ò	Ò	□	Ò	Ò	Ò
Hunting/Trapping	Ò 8	Ò 8	□	Ò	Ò	Ò
Ice Fishing/Ice Skating	Ò	Ò	□	Ò	Ò	□ 9
Shore Fishing	Ò 10	□ 11	□ 12	□ 11	□ 11	□ 12
WATER ACCESS						
Boat Fishing	Ò	Ò	□ 13	□ 14	□ 14	□ 13
Canoeing/Kayaking/Boating	Ò	Ò	Ò	Ò	□ 14	□ 15
Wading (fishing, launching)	Ò 16	□ 17	□ 17	Ò 18	□ 18	□ 16
Swimming	Ò	Ò	Ò	Ò	Ò	Ò
OTHER ACCESS						
Group Activities (e.g., weddings)	□ 19	□ 19	□ 19	Ò	Ò	Ò
Geocaching/Questing	□ 20	□ 20	□ 20	Ò	Ò	Ò
Wildlife/Bird Watching	□ 7	□ 7	□ 7	□ 7	□ 7	□ 7
Night Access	Ò 21	□ 22	□ 22	Ò	Ò	□ 21
Organized Sports	Ò 24	Ò 24	Ò 24	Ò	Ò	Ò
Dogs/ Other Animals	Ò	Ò	Ò	Ò	Ò	Ò
Horseback Riding	Ò	Ò	Ò	Ò	Ò	Ò
Collecting/Metal Detecting	Ò	Ò	Ò	Ò	Ò	Ò
Camping	Ò	Ò	Ò	Ò	Ò	Ò
Fishing Derbies	Ò	Ò	Ò	Ò	Ò	Ò
Target Shooting	Ò	Ò	Ò	Ò	Ò	Ò
Advertising	Ò	Ò	Ò	Ò	Ò	Ò
Marking–Trail/Roads (unauthorized)	Ò	Ò	Ò	Ò	Ò	Ò
Alcohol (possession of)	Ò	Ò	Ò	Ò	Ò	Ò
Other	**Please call the Quabbin Visitor Center 413-323-7221 or Watershed Ranger Station 413-323-0192**					

LEGEND: **Prohibited –** Ò **Allowed - general restrictions –** □ **Specific Conditions –** □ #

[a] The areas on the reservoir above the horseshoe dams at Gates 31 and 43

[b] South Spectacle, Bassett, and Peppers Mill Ponds

General Restrictions:

General public access within the Quabbin Reservoir Watershed System is restricted to one hour before sunrise and one hour after sunset through gates or designated (posted) areas only. Any activity which injures or defaces the property of the Commonwealth is strictly prohibited. This chart is based on the Watershed Protection Regulations 350 CMR 11.00, copies of which are available at the Quabbin Visitor Center. Littering is strictly prohibited. Carry in/Carry out. Don't feed wildlife.

Specific Restrictions:

[1] The Winsor Dam and Goodnough Dike have restricted vehicle access for security reasons.

[2] Snowmobiling is allowed only on the DCR designated trail located on Off-Reservation land. 304 CMR 12.29 applies.

[3] Bicycling is only allowed on designated roads in Quabbin Park. See DCR Bicycling maps. Helmets and protective gear are required by MA law for children under 16 years of age and recommended for others

[4] Bicycling is allowed only on designated roads through DCR gates 29, 30, 31, 35, 40, 43A & B, and 44. Bicycling is only allowed on designated roads through Gate 8 during fishing season. See DCR Bicycling map for designated roads.

[5] Bicycling is allowed on main forest roads only within Off-Reservation lands with seasonal restrictions (e.g., mud season).

[6] Sledding or any other kind of sliding activity is prohibited on the reservoir, the dams and other structures.

[7] Walking, hiking, or snowshoeing access is allowed within the Quabbin Reservoir Watershed system, except in restricted areas (e.g., Prescott Peninsula, posted Administration Areas, Reservoir islands and along the baffle dams-November 15 – June 15).

[8] Hunting and Trapping are prohibited except by special permit during the Quabbin Controlled Deer Hunt and associated Paraplegic Hunt. Contact the Quabbin Visitor Center for more information.

[9] Ice fishing, ice skating, and carry-in boat access allowed on three Off-watershed ponds: South Spectacle, Bassett and Peppers Mill Ponds only. Please call Watershed Rangers, if accessing, as a courtesy at 413-323-0192.

[10] No fishing in Quabbin Park except catch-and-release fly fishing (allowed all year) below the Winsor Dam in the Swift River, unless posted.

[11] Shore fishing along the Reservoir and along streams is permitted between Gates 8-West Branch Swift River, and 22-44 (except on baffle dams), by foot, during the designated Quabbin Fishing Season only. See the current Quabbin Fishing Guide and Map available at the Quabbin Visitor Center.

[12] Shore fishing within off-reservation lands and along off-watershed ponds is allowed year round according to State Fishing regulations.

[13] Carry-in boat access is allowed on off-watershed ponds. See Night Access Policy, if applicable.

[14] Boat access on designated areas of reservoir or regulating ponds requires valid MA Fishing License and size/motor restrictions. Wearing boots is mandatory if wading while launching or removing boats at designated areas from the Reservoir. Fishing access using canoes, kayaks, or jon boats is allowed only through Gate 31 above regulating dam and through Gate 43 on Pottapaug Pond with restrictions. Contact the Quabbin Visitor Center at 413-323-7221 for more information regarding current Fishing Guide.

[15] Allowed subject to MA Boating regulations. Please call Watershed Rangers, if accessing, as a courtesy at 413-323-0192

[16] Wading is allowed Off-watershed below the Winsor Dam Power Station on the Swift River

[17] Wading with boots is allowed between Gate 8-West Branch Swift River, and Gate 22-44, except in restricted areas, and in Off-Reservation tributaries.

[18] Wading is prohibited except while launching or removing boats while wearing boots, at designated boat launch areas.

[19] Allowed without a permit for groups of less than 25 individuals and/or less than 10 cars and/or 10 motorcycles. Permit required for group of 25 through 100 individuals and/or 10-40 cars/motorcycles or 1 bus. Permit and Ranger required for larger groups or other combinations.

[20] Special permit from Visitor Center required for any cache placement.

[21] Night access within Quabbin Park is prohibited with two exceptions. It is allowed without a permit on Swift River below Y pool, if access is from Route 9, and on Peppers Mill Pond.

[22] Night access within Quabbin Reservation is allowed by permit for pedestrians only through Gates 16, 31, 35, 41, and 43 only during the designated Quabbin Fishing season. Night access directly from 122 is allowed without a permit on South Spectacle Pond (off-watershed). Night access is allowed on Off-Reservation lands with special permit. Contact Quabbin Visitor Center for permit information.

[23] South Spectacle, Bassett, and Peppers Mill Ponds.

[24] Prohibited except with written permission from the Commissioner.

2.4.2 Current Forest Conditions

2.4.2.1 Quabbin Forest Types and Acreages

In 1998, Quabbin forestry and natural resources staff, in conjunction with photo interpretation/GIS staff at the University of Massachusetts, began work to complete current forest typing of the DCR/DWSP properties surrounding Quabbin Reservoir, based on digital, aerial orthophotography that was flown in 1993. The forestry staff identified forest types based on a combination of 1 meter and 0.5 meter resolution digital orthophoto quadrangle sheets and field checking as needed, and drew these on mylar overlays. These mylars were registered to the statewide GIS and scanned to produce digital shape files for use in a wide variety of GIS applications. Where changes had occurred since the date of the photography (e.g., red pine plantations converted to mixed native composition), these changes were included in the typing, so that this datalayer can be considered current as of 1998-1999. **Table 18** describes the current composition of the Quabbin forest based on this typing project.

Table 18: Quabbin Forest Types and Acreages

Category	Overstory type	Code	Description	Total Acres	Percent of Total
Softwoods	White pine (WP)	1	Eastern white pine is pure or predominant. Generally moist sandy loam soils.	6,518	11%
Softwoods	White pine / Hemlock (WK)	2	Eastern white pine and eastern hemlock and a large assortment of hardwoods. Pine usually dominates.	2,586	4%
Mixed	White pine / Hardwood (WH)	3	Eastern white pine, northern red oak, and other hardwoods predominate with red maple as the chief associate. Tends to develop into WK.	7,901	14%
Mixed	White pine / Oak (WO)	4	Eastern white pine and northern red oak or black oaks predominate. Type has some chestnut oak but usually black, red, or scarlet oaks plus assorted other hardwoods.	3,770	6%
Softwoods	White pine / pitch pine	5	Past history of fire on dry, sandy soils has established a pitch pine component in this otherwise predominantly white pine type.	9	<1%
Softwoods	Hemlock (HK)	6	Eastern hemlock is pure or predominant over many other associates.	1,654	3%
Mixed	Hemlock / hardwood (HH)	7	Hemlock and yellow birch dominate, with sugar maple, beech, and red oak as associates. Moist sites.	2,922	5%
Softwoods	Norway spruce (NS)	8	Planted Norway spruce	?	<1%
Softwoods	Red / white spruce (RS)	9	Plantations of red and/or white spruce with associated minor component of yellow birch, sugar and/or red maple, and beech	79	<1%

Category	Overstory type	Code	Description	Total Acres	Percent of Total
Softwoods	Larch (tamarack) (TK)	10	Planted larch is pure or predominant. Moist sites.	5	<1%
Softwoods	Red pine (RP)	11	Although able to reproduce naturally, most of this type was planted, sometimes in alternating rows with white pine.	1,550	3%
Hardwoods	Northern red oak (RO)	12	Northern red oak is predominant with other oaks as chief associates.	6,907	12%
Hardwoods	Oak / hardwood (OH)	13	Oaks and hickories dominate stands containing red, white, black, and scarlet oak and other associated hardwoods. Sites are usually moderately well-drained, with average soil depths. Usually not ridgetops.	8,673	15%
Hardwoods	Oak, mixed: dry site (OM)	14	Black and white oaks predominate, although red oak is present, along with red maple and birches. These are frequently poor sites with thin, excessively drained soils, found toward the tops of ridges.	7,005	12%
Wetlands	Wooded wet – deciduous	15	Forested wetlands dominated by red maple with a large number of other associated species.	732	1%
Hardwoods	Black birch/red maple/cherry	16	Black birch and red maple predominate. Generally a pioneer, early-successional type.	1,617	3%
Other types	Poplar / grey birch	17	Also a pioneer type, with paper birch, pin cherry, and red maple as common associates.	225	<1%
Other types	Abandoned orchard	18	Planted fruit trees which persist despite competition, or have been retained by management.	8	<1%
Other types	Grasses / herb cover	19	Land which is maintained in grasses or herbaceous cover but not associated with administrative areas.	311	1%
Other types	Upland brush	20	Recently abandoned fields in a wide mix of tree, shrub, and herbaceous cover.	111	<1%
Wetlands	Marsh	21	Soil is saturated and often covered with six inches to as much as three feet of standing water during the growing season. Wetland and aquatic vegetation may include sedges, cattails, pickerelweed, water lilies, or duckweed.	257	<1%
Hardwoods	Northern hardwoods	22	Moist, rich sites dominated by white ash, sugar maple, yellow birch.	1,973	3%

Category	Overstory type	Code	Description	Total Acres	Percent of Total
Wetlands	Shrub swamp	23	Soil saturated during growing season. Common woody species include alder, buttonbush, dogwood, willow. Tussock sedges also common.	459	1%
Wetlands	Bog	24	Typically acid, peaty, saturated soil with characteristic mat of sphagnum. Black spruce, tamarack, red maple may be present. Also heath shrubs, cranberries, pitcher plants, sedges.	75	<1%
Wetlands	Wooded wet – coniferous	25	Wetlands with a coniferous overstory.	188	<1%
Wetlands	Wooded wet – mixed	26	Wetlands with a mixed conifer/deciduous overstory.	418	1%
Wetlands	Beaver meadow	27	Conditions may resemble other type classes, but originated by beaver.	883	2%
Administrative	Power line	28	Power line on poles or buried telephone or pipe lines.	289	<1%
Administrative	Administration areas	29	Structures, parking areas, fishing areas, others.	154	<1%
Administrative	Lawns, ornamental plantings	30	Areas around administrative buildings, within Quabbin Park, on and adjacent to dams and dikes that are dominated by mowed grass and ornamental plantings.	88	<1%
Administrative	Gravel pit	34	Areas from which gravel is currently or has been historically extracted and are not currently forested.	17	<1%
Hardwoods	Red maple	35	Red maple dominates; hardwood associates include oaks and birches.	1,028	2%
Softwoods total				12,401	21%
Hardwoods total				27,203	47%
Mixed woods total				14,593	25%
Wetland types total				3,012	5%
Other types				655	1%
Administrative total				548	1%
Grand Total				**58,412**	**100%**

For the 54,197 acres typed as non-wet forest land, 23% is dominated by softwoods, 50% is dominated by hardwoods, and 27% is mixed hardwoods and softwoods. Wetlands total 3,012 acres, of which 1,268 are wooded.

2.4.2.2 Exceptional Forests

Both Fred Hunt, who supervised forestry in the early 1960s at Quabbin, and Bruce Spencer, Chief Quabbin Forester from 1965 to 2006, identified areas within the forest that included exceptional individual trees or stands of trees. Hunt referred to a series of exceptional trees he located and mapped as his "museum pieces"; Spencer took the time before his retirement to map areas of exceptional trees or stands that he had found and followed during his 40 years in these woods. All DWSP foresters have at one time or another discovered stands or trees or other landscape features that for one reason or another

greatly surpass the average. There is shared concern that these areas might go unacknowledged if they are not documented and could be inadvertently altered or lost. DWSP has begun an effort to document these areas and to maintain both spatial and database records of their location and significance, and then to prescribe individualized management approaches in order to conserve this resource.

2.4.2.3 Results from Quabbin Continuous Forest Inventory

2.4.2.3.1 Brief History of Continuous Forest Inventory (CFI)

Early in his tenure as Forest and Park Supervisor for DWSP properties in the early 1960s, Fred Hunt recognized the potential value of installing a Continuous Forest Inventory system at Quabbin, based on the USDA Forest Service design. The intent was to gather periodically updated information on the current condition of the forest, sufficient to guide the improvement of both water and forest values on the watershed. The objectives included an assessment of the current vegetative cover against an ideal composition and structure, and the calculation of sustainable periodic yields that might be attained in the process of managing toward that ideal. This system of plots has been remeasured at least every ten years since 1960, producing a valuable, probably unique, record of the growth and change in a large, contiguous, managed forest in central New England. In looking through the sample results shown below, readers should bear in mind that these figures are from a forest that has been under active management since the 1960s, in contrast to much of the forest in Massachusetts. They are also a tribute to the silvicultural care provided by Bruce Spencer, the Chief Forester at Quabbin from 1965 to 2006.

Hunt installed 347 CFI plots at Quabbin beginning in April 1960. Plots were established at the intersections of a ½ mile x ½ mile grid that was laid out over topographic maps covering all of the land under state care and control at Quabbin, including islands. All CFI plots are 1/5 acre in size (52.66 feet in radius) and because they are on a ½ mile grid, each represents 160 acres of the watershed forest, so the initial CFI represented 55,520 acres, the approximate holding at the time. Plot center was identified with a hardwood stake and witness trees. In this first measurement, all softwoods with a diameter at breast height (DBH) of 9.0”and above and all hardwoods 11.0” DBH and above were measured. On a random sample of all plots, all trees greater than 5.0” DBH were measured, in order to sample younger growing stock. Each tree was numbered and that number and the permanent point for measuring DBH were painted on the tree. Data recorded for each tree measured in 1960 included plot and tree number, species, DBH to the nearest 1/10th inch, merchantable height, and various determinations of soundness and product value of the tree. Plot information included forest type, stocking and size class, land use, disturbance, accessibility, and recommended future silviculture.

Full details of the 1960 CFI measurement are included in Hunt’s Masters thesis at the University of Massachusetts. Below are a few highlights from that report:

1. Stands younger than 20 years old occupied less than 8% of the forest; stands older than 60 years old were estimated to occupy even less.
2. Sawtimber on the 55,520 acre forest totaled an estimated 124,455,000 board feet, of which 45% was white pine and 32% was oak. Current value of all sawtimber was estimated at $1,760,580 based on an average stumpage value of $10.60 per thousand board feet. Poletimber was estimated to total about 260,000 cords.
3. The Chestnut blight and the hurricane of 1938 resulted in two-storied stands of sawlog residuals above smaller trees, on a total of about 17,000 acres.
4. 65% of the sawtimber trees, by volume, were rated as good to excellent in vigor. Just 2% of the sawtimber trees were rated as “dying”.
5. Metal was found in about 1% of the total sawtimber by volume, ranging from old fence wire to railroad spikes and horseshoes.
6. The white pine weevil was rated as the most damaging of the biological agents affecting the

forest, while white pine blister rust and gypsy moth were determined to be well under control. Dutch elm disease was finishing off most of the remaining elm trees.

7. Regeneration (trees 3 feet tall to 4.9" dbh) averaged 254 stems per acre, but some areas, and Prescott Peninsula in particular, showed no regeneration of valuable species during the previous fifteen years, because of deer browsing.
8. Annual growth of sawtimber was estimated to be about 4.7 million board feet at that time.

Note that these plots are not removed from management; they are treated according to the prescription for the surrounding stand. The Quabbin CFI plots were remeasured in 1965, 1970, 1980, 1990, and 2000, and partially remeasured in 1995. The variables measured from year to year have changed somewhat, but all trees greater than 5.5" dbh on all plots have been measured since 1965. DBH and some measurement of height and vigor have been recorded consistently, and subplots to measure seedlings and saplings have been added in recent years. As a water supply management agency, DWSP's priority for information from CFI has focused on changes in species composition and size or age class distribution, but the data also allow calculations of growth in volume and value.

2.4.2.3.2 2000 remeasurement

The 2000 CFI remeasurement began at the end of the 2000 growing season and was completed by mid May of 2001. Sonar measuring devices enabled a distance and bearing measurement from plot center for each tree on the plot, making it possible to map and model the spatial components of stand development. A total of 326 plots were measured, 304 of which were also measured in 1990. In addition to tree measurements, plot measurements have been recorded every decade, and the 2000 plot measurements added greater detail on types of disturbances and interference from invasive plants, both native and non-native. Tree data in 2000 included species, DBH, crown class, product lengths and potential, and wildlife value, among others.

There are endless questions that can be addressed by the information in the CFI plots, but only a few of these are summarized in this plan. DWSP first looks at changes in species composition in the most recent decade, by charting the basal area stocking of each species at the beginning and end of the period, and accounting for changes as growth, mortality, or harvesting. **Table 19** shows the results for the most recent decade. These figures show the basal area (square feet at 4.5 feet above the ground) changes on the 304 plots (representing 48,640 managed acres) that were measured in both 1990 and 2000 (there are minor changes in plots measured, for instance due to losses from beaver flooding of plots, or new plots added on land recently acquired).

296 of the 326 plots measured in 2000-2001 were designated as "regular management" plots, 14 plots were located on islands, 6 within designated "natural areas", 9 in areas designated as wetlands, and 1 in an area designated as too steep to manage. Some of these plots had been previously measured in 1980, but not in 1990. As each plot represents 160 acres, the 296 "regular management" plots represent 47,360 acres, which was approximately the acreage in 2000 of actively managed Division-controlled forest surrounding Quabbin Reservoir (>10,000 acres were reserved from active management).

Table 19: Total CFI Basal Area (sq ft) by Species and Changes from 1990 to 2000

Species	1990 BA	% of 1990 BA	BA Died	%	BA Cut	%	Growth	%	New	2000 BA	% of 2000 BA	BA Change	% Change
White pine	1726	26.9%	47	2.7%	254	14.7%	364	21.1%	43	1832	28.2%	106	6%
Red pine	467	7.3%	10	2.1%	303	64.9%	28	6.0%	0	182	2.8%	-285	-61%
Hemlock	529	8.3%	18	3.4%	58	11.0%	97	18.3%	29	579	8.9%	50	9%
Spruces	36	0.6%	3	8.3%	10	27.8%	4	11.1%	0	27	0.4%	-9	-25%
Pitch pine	8	0.1%	3	37.5%	1	12.5%	1	12.5%	0	5	0.1%	-3	-38%
Larch	10	0.2%	0	0.0%	0	0.0%	4	40.0%	0	14	0.2%	4	40%
Red oak	1069	16.7%	6	0.6%	57	5.3%	259	24.2%	10	1275	19.6%	206	19%
Black oak	435	6.8%	11	2.5%	71	16.3%	81	18.6%	7	441	6.8%	6	1%
Scarlet oak	5	0.1%	0	0.0%	1	20.0%	2	40.0%	0	6	0.1%	1	20%
White oak	246	3.8%	9	3.7%	29	11.8%	32	13.0%	6	246	3.8%	0	0%
Chestnut oak	38	0.6%	4	10.5%	2	5.3%	6	15.8%	2	40	0.6%	2	5%
Sugar maple	104	1.6%	2	1.9%	2	1.9%	17	16.3%	3	120	1.8%	16	15%
Red maple	878	13.7%	79	9.0%	100	11.4%	117	13.3%	45	861	13.3%	-17	-2%
Yellow birch	92	1.4%	6	6.5%	5	5.4%	12	13.0%	4	97	1.5%	5	5%
Black birch	296	4.6%	10	3.4%	43	14.5%	56	18.9%	21	320	4.9%	24	8%
White birch	111	1.7%	20	18.0%	18	16.2%	10	9.0%	3	86	1.3%	-25	-23%
Beech	9	0.1%	2	22.2%	1	11.1%	3	33.3%	0	9	0.1%	0	0%
White ash	218	3.4%	20	9.2%	11	5.0%	37	17.0%	3	227	3.5%	9	4%
Hickory	85	1.3%	3	3.5%	3	3.5%	11	12.9%	2	92	1.4%	7	8%
Elm	3	0.0%	2	66.7%	0	0.0%	0	0.0%	0	1	0.0%	-2	-67%
Poplar	12	0.2%	2	16.7%	0	0.0%	2	16.7%	0	12	0.2%	0	0%
Tupelo	3	0.0%	0	0.0%	0	0.0%	0	0.0%	0	3	0.0%	0	0%
Butternut	1	0.0%	1	100.0%	0	0.0%	0	0.0%	0	0	0.0%	-1	-100%
Black cherry	28	0.4%	3	10.7%	7	25.0%	2	7.1%	1	21	0.3%	-7	-25%
Ironwood	1	0.0%	0	0.0%	0	0.0%	0	0.0%	0	1	0.0%	0	0%
Grey birch	2	0.0%	1	50.0%	0	0.0%	0	0.0%	0	1	0.0%	-1	-50%
Totals	**6412**	**100%**	**262**	**4.1%**	**976**	**15.2%**	**1145**	**17.9%**	**179**	**6498**	**100%**	**86**	**1.3%**

In 1998-1999, DWSP staff completed a project to update forest typing (see Section 1.10.2.3), using the most recent digital orthophotography and field surveys and digitizing the results to the DCR GIS. A comparison between the mapped acreage of forest types and the acres of each type represented by the current CFI was completed to verify representation. Results of this comparison are shown in **Table 20**. Some of the smaller forest types, such as coniferous wooded wetlands and pure red maple types are under-represented, while the largest over-representations are with the white pine/oak and the dry site oak types. The explanation may be the overlap between these types and others, such as white pine/hardwood or oak/hardwood, which are underrepresented by the current CFI. Note also that the typing of CFI plots is somewhat more localized than landscape level forest typing.

Table 20: CFI Plot Distribution Compared to Acreages by Forest Type

All plots, including islands, wetlands, etc (each 1/5 acre plot represents 160 acres of the forest)						
Overstory code	**Overstory name**	**# of CFI plots**	**Acres represented**	**Acres in GIS**	**Difference**	**CFI plots needed**
1	White pine	39	6,240	6,518	278	2
2	White pine / hemlock	6	960	2,586	1,626	10
3	White pine / hardwood	41	6,560	7,901	1,341	8
4	White pine / oak	41	6,560	3,770	(2,790)	(17)
5	White pine / pitch pine	0	-	9	9	0
6	Hemlock	3	480	1,654	1,174	7
7	Hemlock / hardwood	24	3,840	2,922	(918)	(6)
8	Norway spruce	0	0	- ? -	-	-
9	Red / white spruce	1	160	79	(81)	(1)
10	Larch	1	160	5	(155)	(1)
11	Red pine	12	1,920	1,550	(370)	(2)
12	Red oak	42	6,720	6,907	187	1
13	Oak / hardwood	45	7,200	8,673	1,473	9
14	Oak, mixed: dry site	57	9,120	7,005	(2,115)	(13)
15	Wooded wet - deciduous	5	800	732	(68)	(0)
16	Black birch/red maple/cherry	8	1,280	1,617	337	2
17	Poplar / grey birch	0	-	225	225	1
18	Abandoned orchard	0	-	8	8	0
19	Grasses / herb cover	1	160	311	151	1
20	Upland brush	1	160	111	(49)	(0)
21	Marsh	1	160	257	97	1
22	Northern hardwoods	20	3,200	1,973	(1,227)	(8)
23	Shrub swamp	1	160	459	299	2
24	Bog	1	160	75	(85)	(1)
25	Wooded wet - coniferous	0	-	188	188	1
26	Wooded wet - mixed	2	320	418	98	1
27	Beaver meadow	4	640	883	243	2
28	Powerline	0	-	289	289	2
29	Administration areas	1	160	154	(6)	(0)
30	Lawns, ornamental plantings	0	-	88	88	1
34	Gravel pit	0	-	17	17	0
35	Red maple	2	320	1,028	708	4
Total		**359**	**57,440**	**58,412**	**972**	**6**

2.4.2.3.3 Species Distribution

Based on the basal area totals from the 11,000+ trees in the 2000 CFI remeasurement, the current distribution of individual tree species across the Quabbin DWSP properties is shown in **Table 21**. On this basis, white pine still dominated the stocking, followed by red oak and red maple. Hemlock still represented 8.9% of the stocking total in 2000, a figure which is likely to decline in the next decade. Early successional or pioneer species such as white birch, poplar, and grey birch occupy minor

components of the forest. Butternut, an endangered species due to disease, has all but disappeared from the watershed.

Table 21: Tree Species Distribution in 2000 CFI

Species	2000 BA	% Total
White pine	1832	28.2%
Red oak	1275	19.6%
Red maple	861	13.3%
Hemlock	579	8.9%
Black oak	441	6.8%
Black birch	320	4.9%
White oak	246	3.8%
White ash	227	3.5%
Red pine	182	2.8%
Sugar maple	120	1.8%
Yellow birch	97	1.5%
Hickory	92	1.4%
White birch	86	1.3%
Chestnut oak	40	0.6%
Spruces	27	0.4%
Black cherry	21	0.3%
Larch	14	0.2%
Poplar	12	0.2%
Pitch pine	5	0.1%
Scarlet oak	6	0.1%
Beech	9	0.1%
Elm	1	0.0%
Tupelo	3	0.0%
Butternut	0	0.0%
Ironwood	1	0.0%
Grey birch	1	0.0%

2.4.2.3.4 Size Distribution

In the year 2000 Continuous Forest Inventory, measurements were taken on 10,342 live trees that were greater than 5.6 inches in diameter at breast height (4.5 feet). These trees are placed in diameter classes for convenience, which accumulate all the trees that are between 0.6 inches less and 0.5 inches more than the diameter (e.g., a tree that is 5.6” to 6.5” DBH would be classified as a 6 inch diameter tree). The distribution of size classes is shown in **Table 22**.

Table 22: Diameter Distribution on CFI in 2000

DBH	# of Trees	% of Total
6	1,548	14.97%
7	1,384	13.38%
8	1,182	11.43%
9	1,076	10.40%
10	954	9.22%
11	813	7.86%
12	677	6.55%
13	615	5.95%
14	435	4.21%
15	333	3.22%
16	290	2.80%
17	231	2.23%
18	200	1.93%
19	165	1.60%
20	118	1.14%
21	77	0.74%
22	65	0.63%
23	45	0.44%
24	27	0.26%
25	28	0.27%
26	24	0.23%
27	15	0.15%
28	9	0.09%
29	13	0.13%
30	5	0.05%
31	6	0.06%
32	-	0.00%
33	3	0.03%
34	1	0.01%
35	1	0.01%
36	-	0.00%
37	1	0.01%
45	1	0.01%
Total	**10,342**	**100.00%**

2.4.2.3.5 Volumes and Growth

Total standing volume in board feet, by species, was calculated using the Form 78 International ¼" Rule for sawlog volumes, a standard measure used frequently in Massachusetts (**Table 23)**. On this basis, White Pine continues to dominate the forest, representing twice as much volume as Red Oak, the second most abundant species by sawlog volume. Hemlock in 2000 carried the third greatest volume of all species, a further testament to the importance of this species that unfortunately is being gradually diminished by an exotic insect pest, the Hemlock Woolly Adelgid (see section 5.2.3).

The total standing volume estimated in 2000 was 527,300,000 board feet. The standing volume in 1960, when Fred Hunt first measured the CFI plots, was estimated at 124,455,000 board feet. Between these two years, the Division has completed approximately 1,000 timber sales, which removed approximately 130 million board feet in improvement thinnings and regeneration harvests, yet forest sawlog volumes grew by 424%, or 10.6% annually *above and beyond* the harvesting that took place in this period. **Table 24** utilizes the volume estimates from the 1990 CFI remeasurement to compare to the volume estimates

from the 2000 CFI remeasurement, in order to generate a current growth rate by species. Based on this calculation, the average annual growth was 282 board feet per acre across the Division forest at Quabbin. The total annual growth for the forest was estimated at more than 15 million board feet, so that the estimated annual harvest of 7.5 million board feet was just under 50% of the annual growth (actual annual harvest rates average approximately 5 million board feet, or 33% of the estimated annual growth).

Table 23: Sawlog Volumes by Species Based on 2000 CFI

Species	Standing Board Foot Volume in 2000	Board Foot Volume as Percent of Total
White Pine	230,058,000	43.6%
Red Oak	115,407,000	21.9%
Hemlock	39,265,000	7.4%
Black Oak	28,810,000	5.5%
Red Maple	27,799,000	5.3%
Red Pine	23,806,000	4.5%
White Oak	14,151,000	2.7%
White Ash	13,459,000	2.6%
Black Birch	12,402,000	2.4%
Sugar Maple	5,783,000	1.1%
Other Softwoods	5,316,000	1.0%
Yellow Birch	4,107,000	0.8%
Paper Birch	3,576,000	0.7%
Other Hardwood	2,864,000	0.5%
Scarlet Oak	497,000	0.1%
TOTAL	**527,300,000**	**100.0%**

Table 24: Annual Board Foot Volume Growth Estimated from 1990 and 2000 CFI Measurements

		GROWTH		HARVEST	
Overstory Type	**Acres (GIS)**	**Av Annual BF/acre**	**Total annual BF growth**	**Av Annual BF/ac cut**	**Total annual BF cut**
White pine	6,518	506	3,297,109	376	2,451,944
White pine/hemlock	2,586	389	1,005,716	102	264,834
White pine/hardwood	7,901	345	2,721,975	141	1,116,837
White pine/oak	3,770	359	1,354,902	104	390,903
Hemlock	1,654	276	457,193	281	465,100
Hemlock/hardwood	2,922	253	738,096	48	139,875
Spruce	79	431	34,029	44	3,454
Larch	5	636	3,180	0	0
Red pine	1,550	359	556,485	683	1,058,205
Red oak	6,907	237	1,638,468	11	74,235
Oak/hardwood	8,673	203	1,757,011	35	307,494
Oak mixed, dry site	7,005	167	1,167,911	46	323,409
Wooded wet - deciduous	732	199	145,879	0	0
Birch/maple/cherry	1,617	199	321,304	0	0
Northern hardwoods	1,973	185	365,440	301	593,297
Wooded wet - conifers	188	16	3,016	0	0
Red maple	1,028	50	51,121	0	0
Total	**55,108**	**282**	**15,524,694**	**136**	**7,502,702**

2.4.2.4 Regeneration Conditions

The Division has been monitoring the conditions of tree regeneration in the forest understory at Quabbin intensively since 1989, primarily to provide guidance for efforts to control the impacts of white-tailed deer. The regeneration monitoring program and current status is detailed in Appendix IV at the back of this plan. By way of summary of current conditions, the deer impact control program has been very successful. In the 15 years between the pre-control sampling in 1989 and the most recent watershed-wide sampling, regeneration has recovered dramatically (**Table 25**), with regeneration that is above 4.5 feet (the upper height of deer browsing) increasing ten-fold on areas within Quabbin Reservation, where hunting had been prohibited until 1991. (NOTE: also see **Appendix IV**). There remain shortfalls in some of the species that are most highly preferred by deer, and black birch and white pine continue to be the strongest component of the on-Reservation regeneration response, but overall, deer control has been very effective in recovering the regenerative ability of the forest. So long as deer populations are maintained at close to current levels, the greatest threat to regeneration in the coming decade may be from an expansion of the moose populations. A moose weighs approximately ten times the weight of a deer. An individual moose consumes approximately 50 pounds of green biomass per day to maintain its mass.

Table 25: Tree Regeneration 1989 vs. 2004

Area	Year	Regeneration 1 ft tall to 4.5 feet	Regeneration > 4.5	Total regeneration
Off Reservation	1989	1,960 stems per acre	1,140 stems per acre	3,100 stems per acre
	2004	2,071	1,404	3,475
On Reservation	1989	770	130	910
	2004	3,187	1,344	4,531

(Note: see Appendix IV for regeneration species composition and other details)

2.5 Quabbin Wildlife

2.5.1 Current Conditions

All species of wildlife depend on the existence and quality of various habitat types. Some species require a very specific habitat to survive (e.g., wood frogs and vernal pools), while other species can exist in a variety of habitats (e.g., coyote). The Quabbin watershed is comprised of a mosaic of habitats. DCR owned land within the watershed is largely forested, while privately owned lands are comprised of small farms, fields, woodlots, and residential areas. Although as a whole the landscape is fragmented, DCR owned land within the watershed is large and relatively contiguous. The undeveloped and relatively unbroken nature of these lands is a tremendous benefit to all wildlife species.

Quabbin supports an impressive variety and abundance of wildlife. Forests provide habitat for a diversity of birds and mammals, including moose, white-tailed deer, turkey, grouse, fisher, and bears. In addition, Neotropical migrant birds, including black and white warblers, rose-breasted grosbeaks, and scarlet tanagers utilize DCR forests for breeding and migratory rest stops. The Quabbin is dotted with wetlands, streams, and beaver ponds which support a variety of reptiles, amphibians, and birds. There are several large tracts of early successional non-forested habitat within the Quabbin watershed. These large open, grassy areas provide habitat for a variety of species dependent on open lands including eastern meadowlarks, bobolinks, and a variety of invertebrates.

One of the most important aspects of DCR land in the Quabbin watershed for wildlife is its protection from development. Towns across Massachusetts continue to experience growth, often resulting in the

loss of open space. The protection DCR lands provide to wildlife species is critical to their long-term survival.

A variety of wildlife species are monitored by Division personnel or other agencies. Breeding bird surveys are conducted yearly along roadsides at two locations. In addition, selected vernal pools are visited, common loons are closely monitored, and the wintering bald eagle population is surveyed each year.

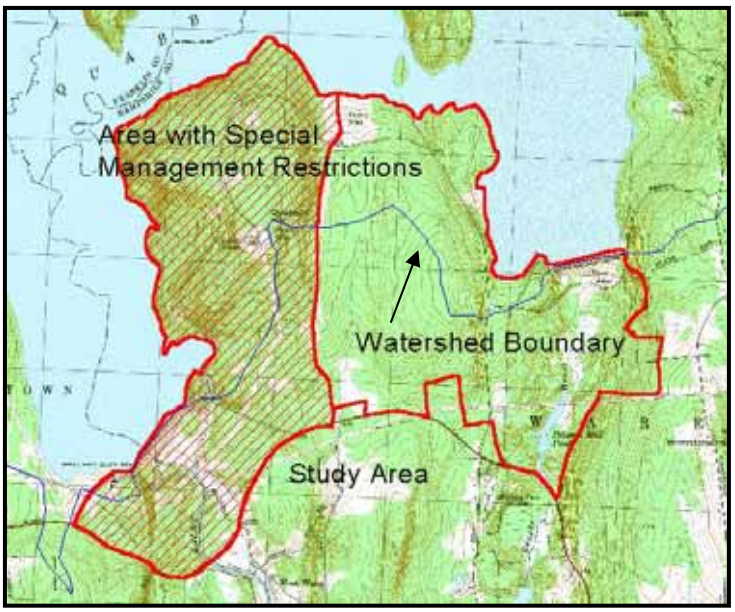
While a great deal of information exists about certain wildlife taxa (e.g., birds and mammals) through information collected from surveys and observations, very little is known about other Quabbin wildlife. A complete species list does not exist, and there is a paucity of information about reptiles, amphibians, insects, butterflies, dragonflies, and other less visible species. It is quite possible that DCR lands within the Quabbin harbor state listed species that have yet to be documented.

2.5.2 Results from Periodic Wildlife Surveys

2.5.2.1 Quabbin Park Deer Population Survey

Quabbin Park, located at the southern end of the Quabbin Reservation, is approximately 3,400 acres in size (**Figure 9**). The Park is the most visited destination of the Reservation, with over 500,000 people visiting the area annually. An extensive network of trails criss-cross the park and provide passive recreation for both occasional visitors and daily walkers. In addition, the Visitor Center, a lookout tower, and several scenic vistas attract educational and recreational groups.

Figure 9: Map of Quabbin Park



Quabbin Park has not been included in the Division's annual managed deer hunt. White-tailed deer management within the Park has consisted only of experiments with electrified deer fencing. Because deer control using electric fences proved unsuccessful within the Park, the Division decided to re-evaluate conditions within the Park and began to examine deer herd densities. A pilot study was initiated in the fall of 2000 to try to assess the feasibility of using distance sampling to study deer densities in the Park. Results from the 2000-2001 pilot study indicated that deer densities were high enough within the Park to initiate a distance sampling study. The objectives of this study were to:

1. Establish a set of random transects within Quabbin Park and develop a protocol for monitoring deer densities from year to year.
2. Estimate deer densities within Quabbin Park during winters 2001-2002 and 2002-2003.

Forty and thirty-eight transects were conducted during 2001-2002 and 2002-2003, respectively (**Table 26**). Surveys started in early to mid November, and the last surveys took place during March of the following year. The average time it took for a single observer to complete a survey was 62.9 and 72 minutes during 2001-2002 and 2002-2003, respectively.

Table 26: Details of Quabbin Park Line-transect Surveys, 2001-2003

	2001-2002	2002-2003
Number of surveys	40	38
Number of km walked	77.05	75.43
Number of observations	75	68
Number of deer seen	248	264
Dates of survey	9 Nov. 2001-7 March 2002	21 Nov. 2002-28 March 2003

Six transects were utilized during the 2001-2002 season. Two new transects were added prior to the 2002-2003 season (**Table 27**). Transects were walked at various times throughout the morning and into early afternoon. Although surveys took place at various times, effort was made to conduct most surveys during early morning and mid-day periods of deer activity in order to optimize effort. On particularly cold or windy days, surveys were conducted at various times throughout the day, because deer were much more likely to be active on these days.

Table 27: Details of Survey Effort for Line-transect Survey in Quabbin Park, 2001-2003

		# Times Surveyed		# Deer Seen	
Transect #	**Length (m)**	**2001-2002**	**2002-2003**	**2001-2002**	**2002-2003**
1	1,978	6	3	11	7
2	1,998	6	6	76	67
3	2,523	1	3	0	19
5	1,790	10	6	102	30
6	1,657	7	5	29	68
7	2,117	10	4	30	10
8	1,849	N/A[1]	4	N/A	39
9	2,406	N/A	7	N/A	34
Total		**40**	**38**	**248**	**264**

[1] Transects 8 and 9 were created prior to the 2002-2003 field season.

Density was estimated using the half-normal + Hermite model of the detection function for both years (Buckland, et al., 1993). The estimated number of deer within Quabbin Park was 233 during the 2001-

2002 study and 247 during the 2002-2003 study (approximately 94 deer per square mile). The estimated effective strip width (ESW) was 44.3 meters and 45.5 meters for 2001-2002 and 2002-2003, respectively. The coefficient of variation for 2001-2002 was approximately 20%. The encounter rate accounted for 61% of the variance in the density estimate. Detection probability accounted for 21.5%, and cluster size variation accounted for the remaining 17.6%. The coefficient of variation for the 2002-2003 season was approximately 19%. Again, the encounter rate accounted for most (56.8%) of the variance in the density estimate. Detection probability and cluster size accounted for 26.6% and 16.6%, respectively.

2.5.2.2 Annual Prescott Beaver Survey Results

Beaver populations in Massachusetts have undergone dramatic changes. By the mid-1700s beaver were extirpated from the state. They were absent from the landscape for close to 200 years until their gradual return in the early 1920s. Beaver were first observed on the Prescott Peninsula in 1952. In 1952, 1960, 1966, and 1968 the number of beaver colonies on the Peninsula was noted through anecdotal records and aerial photographs. From 1969 until the present, annual autumn food cache surveys have been conducted.

Annual surveys of the Peninsula are typically conducted during November each year. A complete shoreline survey is conducted by boat. In addition, all streams, ponds, and other potential habitats on the interior are walked. Active sites are determined by the presence of a food cache and other activity. Active sites are noted, and Universal Transverse Mercator coordinates are recorded.

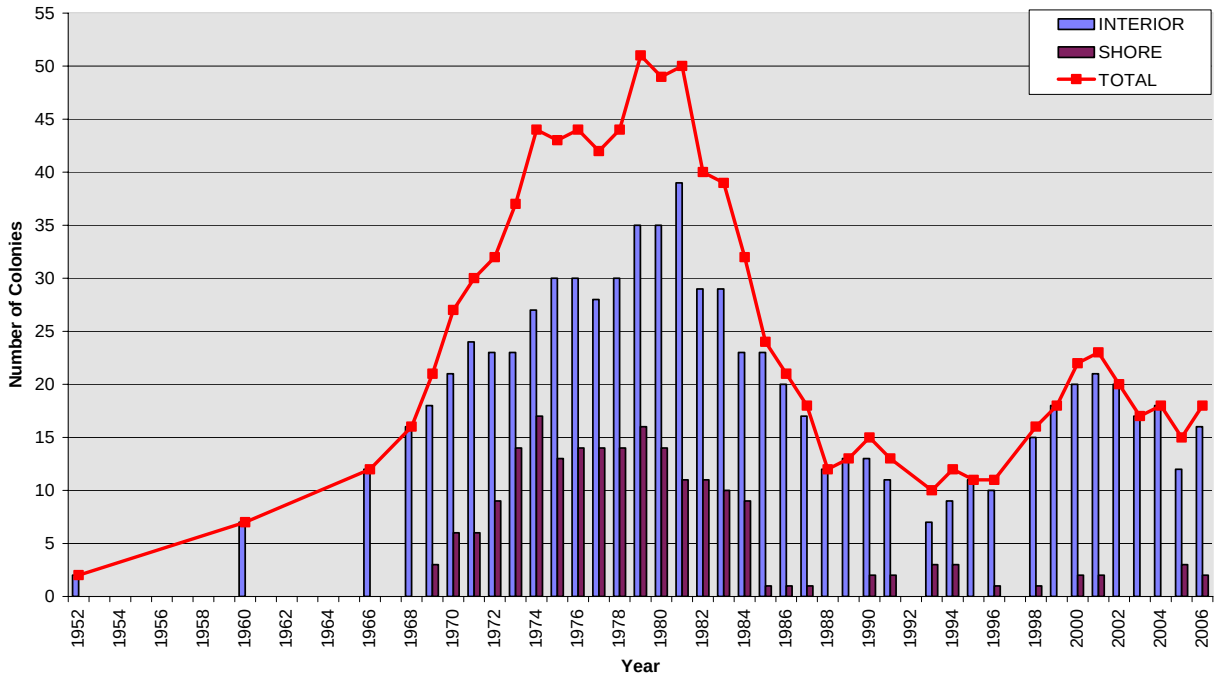
Beaver populations on Prescott Peninsula experienced 6 phases of growth and decline (**Figure 10**). From 1952 until approximately 1966, beaver populations on the Peninsula increased gradually. The number of colonies grew from 2 to 12. From 1967 until 1974, beaver populations entered their second phase which was characterized by a rapid increase in population. In only 7 years, beaver colonies increased from 12 to 44 colonies.

Between 1975 and 1982, the population was in its third phase characterized by high densities with some year to year fluctuation. The fourth phase of the population took place during 1983 to 1988. During this period, the number of beaver colonies decreased dramatically, from a high of 44 to a low of 12. Contributing to this overall decline was a reduction in the number of shoreline colonies. In 1983, there were 10 shoreline colonies, in 1987 there was only one and by 1988 there were no shoreline colonies present.

The fifth phase of the population lasted between 1988 and 1996. This phase is distinguished by relatively stable populations at low levels. The number of colonies during this period ranged between 10 and 15. In addition, this period had very few shoreline colonies.

The beaver population is currently in its sixth phase which has lasted since 1997. During this phase, populations increased slightly to a high of 23 in 2001. Since 2001, populations have declined slightly to a low of only 15 during 2005. As in phase 5, the number of shoreline colonies in phase 6 has remained relatively low.

Figure 10: Beaver Survey Results from Prescott Peninsula, 1952-2006



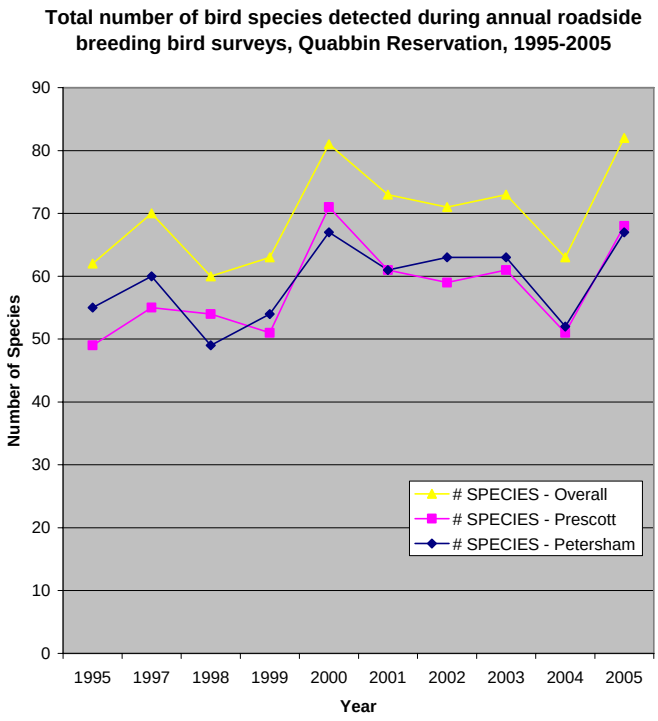
2.5.2.3 Roadside Breeding Bird Surveys

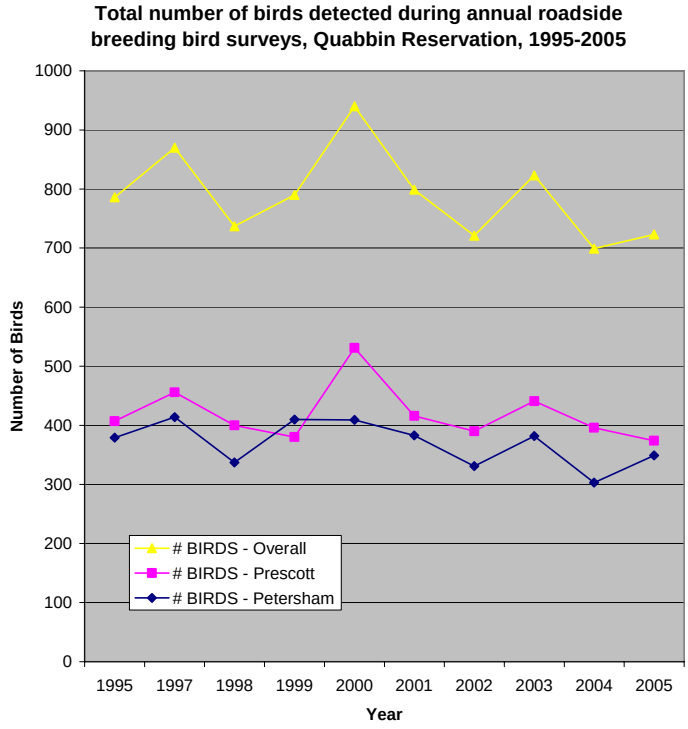
Roadside breeding bird surveys have been conducted yearly at Quabbin since 1988. Surveys are conducted along two routes. The first route is located in the Petersham area, and the second route is located on Prescott Peninsula. Stations are located adjacent to the interior roads and are approximately ½ mile apart. There are 16 stations on the Petersham route and 20 stations on the Prescott route. At each station, a listener and recorder note all individual birds either seen or heard during a three minute listening period. Surveys are conducted during early June each year to coincide with the active breeding period of migratory and resident birds.

Data from 1995 to 2005 indicate a slight increase in the number of bird species detected during the 10 year period (**Figure 11**). However, data also indicate a slight decline in the overall number of birds detected during this same period. While it appears that more species are being seen during the annual surveys, there are fewer individuals of those species being detected.

Data from roadside surveys can be useful in providing general trends in bird species and abundance; however, caution should be used when interpreting the data. Because survey stations were located adjacent to interior roads, results may not reflect species trends of forest interior migratory birds. Roadside surveys would favor edge species, common resident species, and species found in early successional non-forested habitat (several stations are adjacent to this habitat type).

Figure 11: Total Number of Birds and Bird Species Recorded During Annual Roadside Surveys, 1995-2005





2.5.2.4 Moose Survey

Annual surveys of moose sign (droppings, browsing evidence at least five feet above the ground, tracks, bark stripping, or moose beds) have been conducted on the Ware River watershed since 2002. In 2003, a moose sign survey was initiated at Quabbin on the Prescott Peninsula. Twenty-five monitoring plots were established and were visited during 23-25 April, 2003. Moose sign was detected on 11 plots (44%). The remaining 14 plots (56%) did not contain moose sign or contained sign that was greater than 1 year old. These surveys for moose sign are supplemented by observations of moose browsing (five feet above the ground, or breaking of tall saplings to reach browse) during annual regeneration surveys.

Since 2003, staffing issues have prevented the Quabbin moose sign survey from being done. However, efforts are being made to restart this program in the near future.

2.6 Quabbin Biological Diversity

2.6.1 Historic Trends

Habitat diversity generally drives biological diversity. The amount and types of habitat at Quabbin have been exceptionally dynamic since early colonial times. Dramatic changes in land use punctuated by periodic climatic events have shaped and changed the landscape and affected the number and types of habitats, plant communities, and plant and animal species. Once covered by virgin forest, the landscape was chronically altered by the activities of Native Americans, and a majority of the land in the Quabbin watershed was cleared for agriculture during colonial times. Land clearing and conversions persisted for

decades, peaking around 1840 when 75 percent of the arable land in Massachusetts was in pasture or farm crops (DeGraaf et al., 1992). When agriculture dominated the landscape, species relying on extensive tracts of forest land were much less numerous. Black bears, wild turkeys, and white-tailed deer were gone from most of their former range. Bluebirds, bobolinks, vesper sparrows, and golden-winged warblers were abundant during this agricultural period, but today are very rare breeders. Field and brushland habitats and communities were more common than today, while forested communities were present but less common.

Through the late 1800s and into the early 20th century, farms were gradually abandoned as better lands and transportation opened in the West. White pine established itself in these abandoned fields and grew until the 1920s when extensive cutting took place to remove the pine. This represented the last large-scale land clearing in the region. Most of the cut pine sites regenerated to hardwoods, initially producing extensive tracts of early successional forested habitat. Among other species, ruffed grouse, rabbits, and a variety of songbirds flourished in this preferred habitat.

The 1938 hurricane blew down extensive areas of maturing forested habitat, particularly pine stands. This created additional areas of early successional forested habitat and species adapted to early successional habitat continued to thrive, while those species dependant on non-forested habitat became less common.

The last dramatic anthropogenic change to the Quabbin landscape took place during the 1930s when the reservoir was created. Approximately 24,000 acres of land were submerged when the reservoir was filled, creating 181 miles of shoreline (including islands) and a 412 billion gallon reservoir. While thousands of acres of terrestrial habitat were lost when the reservoir filled, a unique and important habitat was created. A variety of species benefited from the creation of the reservoir. Bald eagles and common loons began their statewide recovery at Quabbin.

Today, the vast majority of Division land within the Quabbin watershed is covered by maturing stands of trees of a variety of species. Very little of Quabbin is occupied by early successional forested or non-forested habitat. The broad and dramatic changes in the landscape during the last 300 years have shaped the current wildlife community. Species suited to mature forests with relatively closed canopies have thrived at Quabbin. White-tailed deer, turkey, moose, and a variety of forest interior song birds are abundant on the Reservation. On the other hand, species that were once abundant because of the extensive tracts of fields and young forests have declined substantially. Golden-winged warblers, upland sandpipers, eastern towhees, and grasshopper sparrows are now either absent from the landscape or are very uncommon.

Epigaea repens, Trailing arbutus, the Massachusetts state flower.

2.6.2 Biodiversity: Current Conditions

2.6.2.1 General conditions

The forests, wetlands, water bodies, rock outcrops, islands, open areas, and other features within the Quabbin Reservoir watershed combine to form a landscape diverse in habitat conditions, although some habitats are certainly more common than others. In spite of its current "wild" appearance, the vast majority of this landscape was cut, grazed, or plowed at some point during the past 300 years of human use. While the forest has now recaptured the majority of the watershed, the legacy of past land use remains in

both obvious (stone walls, roads, plantations) and less obvious (persistent changes in soil chemistry and physical properties; species composition) ways. The dominant habitat types are maturing forest cover and the massive water body of the reservoir, while open land areas and young forests are less common. The extensive list of floral and faunal species shown in **Tables 28-29** and **Appendix III** are supported by these dominant habitats as well and/or by a wide diversity of less common habitat types and natural communities.

2.6.2.2 Quabbin Flora, Common and Uncommon

During 1995 and 1996, the Division contracted with the University of Massachusetts Herbarium to inventory proposed harvesting areas for the presence of rare plant species. During this inventory, the Herbarium also compiled a general flora, a list of all species encountered. The list of the species encountered at Quabbin is included as **Appendix III.** Within this list, a small number of rare or uncommon species were encountered and populations of state-listed species have been located and recorded with Natural Heritage during independent surveys of Quabbin properties within the past 10 years (**Table 28**).

Table 28: State Listed Plants Occurring on DWSP Quabbin Properties

Species	Common Name	Status
Adlumia fungosa	Climbing Fumitory	T
Chenopodium simplex	Maple-leaf Goosefoot	WL
Clematis occidentalis	Purple or Mountain Clematis	SC
Gentiana linearis	Narrow-leaved Gentian	WL
Gentianopsis crinita	Fringed Gentian	WL
Juglans cinerea	Butternut	WL
Liatria scariosa var nova-angliae	New England Blazing Star	E
Mimulus moschatus	Musky Monkey-flower	T
Moneses uniflora	One-flowered Pyrola	WL
Panax quinquefolius	Ginseng	SC
Poa languida	Drooping Speargrass	E

NOTE: For Status, E = endangered, T = threatened, SC = special concern, WL = watch list

In addition to the rare or uncommon species highlighted above, there are uncommon species that have some likelihood of being found at Quabbin, were a comprehensive inventory initiated. These are listed in **Table 29**, and are based on historic records from the UMass herbarium and other sources.

Table 29: Uncommon Plants Potentially Occurring on DWSP Properties

Family	Species	Common Name	Status	Flowering
Apiaceae	*Conioselium chinense*	Hemlock Parsley	SC	Jul/Sep
Apiaceae	*Sanicula trifoliata*	Trefoil Sanicle	WL	Jun/Oct
Asclepiadaceae	*Asclepias verticillata*	Linear-leaved Milkweed	T	May/Jul
Asteraceae	*Aster radula*	Rough Aster	WL	Jun/Aug
Brassicaceae	*Arabis drummondii*	Drummond's Rock-cress	WL	May/Aug
Brassicaceae	*Arabis missouriensis*	Green Rock-cress	T	Jul/Oct
Brassicaceae	*Cardamine bulbosa*	Spring Cress	WL	Jun/Aug
Caryophyllaceae	*Stellaria borealis*	Northern Stitchwort	WL	May/Aug

Family	Species	Common Name	Status	Flowering
Cyperaceae	*Eleocharis intermedia*	Intermediate Spikerush	T	Aug/Oct
Cyperaceae	*Scirpus ancistrochaetus*	Barbed-bristle Bulrush	E	Jun/Jul
Fabaceae	*Lupinus perennis*	Wild Lupine	WL	May/Jul
Gentianaceae	*Gentiana andrewsii*	Andrew's Bottle Gentian	T	Apr/Jun
Gentianaceae	*Gentiana linearis*	Narrow-leaved Gentian	WL	Jun/Aug
Haloragaceae	*Myriophyllum alterniflorum*	Alternate-leaved Milfoil	T	Jun/Aug
Juncaceae	*Juncus filiformis*	Thread Rush	T	Aug
Lentibulariaceae	*Utricularia minor*	Lesser Bladderwort	WL	May/Nov
Liliaceae	*Smilacina trifolia*	Three-leaved Solomon	WL	Apr/Jun
Loranthaceae	*Arceuthobium pusillum*	Dwarf Mistletoe	SC	May/Sep
Orchidaceae	*Coeloglossum viride v. bracteata*	Frog Orchid	WL	May/Sep
Orchidaceae	*Corallorhiza odontorhiza*	Autumn Coralroot	SC	Apr/Jul
Orchidaceae	*Cypripedium calceolus v. parviflorum*	Small Yellow Lady Slipper	E	May/Aug
Orchidaceae	*Cypripedium calceolus v. pubescens*	Large Yellow Lady Slipper	WL	Jun/Sep
Orchidaceae	*Isotria medeoloides*	Small-whorled Pogonia	E	May/Jul
Orchidaceae	*Platanthera hookeri*	Hooker's Orchid	WL	Mar/Jun
Orchidaceae	*Platanthera macrophylla*	Large-leaved Orchis	WL	Apr/Jul
Orchidaceae	*Platanthera. flava var. herbiola*	Pale Green Orchis	T	Jun/Sep
Orchidaceae	*Triphora trianthophora*	Nodding Pogonia	E	Jul/Sep
Poaceae	*Panicum philadelphicum*	Philadelphia Panic Grass	SC	Jul
Poaceae	*Trisetum pensylvanica*	Swamp Oats	T	Aug/Oct
Poaceae	*Trisetum spicatum*	Spiked False Oats	E	Jul/Sep
Ranunculaceae	*Ranunculus alleghaniensis*	Allegheny Buttercup	WL	Jun/Sep
Sparganiaceae	*Sparganium angustifolium*	Narrow-leaved Bur Weed	WL	May/Nov
Urticaceae	*Parietaria pensylvanica*	Pellitory	WL	Aug/Sep

Working with the University of Massachusetts Herbarium, DWSP has also identified likely habitat/rare species relationships in the Quabbin area (**Table 30**). Some, but not all of these species have been located in the Quabbin area.

Table 30: Habitats in which Rare Species are Likely to be Found in the Quabbin Reservoir Watershed

Species	Common name	Comments
Forested Areas		
Rich Mesic Woods (less acid - rich herbaceous layer. Indicators: *Acer saccharum*, *Fraxinus americana*, *Adiantum pedatum*, *Asarum canadense*)		
Acer nigrum	Black Maple	
Cerastium nutans	Nodding Chickweed	
Coeloglossum viride v. bracteata	Frog Orchid	to dry rocky woods

Species	Common name	Comments
Corallorhiza odontorhiza	Autumn Coralroot	to dry/seasonally wet streamlets
Cypripedium calceolus v. pubescens	Large Yellow Lady Slipper	slopes and talus
Equisetum pratense	Horsetail	sandy places
Panax quinquefolius	Ginseng	talus and base of ledge areas
Platanthera hookeri	Hooker's Orchid	often rocky or swampy
Ranunculus alleghaniensis	Allegheny Buttercup	rocky
Ribes lacustre	Bristly Black Current	
Sanicula canadensis	Canadian Sanicle	
Sanicula gregaria	Long-Styled Sanicle	
Sanicula trifoliata	Trefoil Sanicle	
Moist Coniferous/Pine Woods		
Goodyera repens	Dwarf Rattlesnake Plantain	pine woods
Moneses uniflora	One-Flowered Pyrola	moist rich woods
Hemlock-Northern Hardwoods		
Isotria medeoloides	Small-whorled Pogonia	vernally moist areas
Platanthera macrophylla	Large leaved Orchis	moist ravines, limey
Rhododendron maximum	Rhododendron	hemlock island in swamp
Triphora trianthophora	Nodding Pogonia	depressions under beech
Viola renifolia	Kidney Leaved Violet	damp rich woods
General Habitat		
Boulder/Talus Slope/Ledges		
Adlumia fungosa	Climbing Fumitory	shaded limey talus
Amelanchier sanguinea	Roundleaf Shadbush	ledges & ridge tops
Arabis drummondii	Drummond's Rock-cress	
Arabis missouriensis	Green Rock-cress	open rock and scree
Chenopodium gigantospermum	Maple-leaf Goosefoot	shaded dry ledges
Clematis occidentalis	Purple Clematis	exposed ledges & talus
Parietaria pensylvanica	Pellitory	shaded shelves
Pinus resinosa	Red Pine (as native)	exposed, rocky ridge tops
Rosa blanda	Smooth rose	dry to mesic rocky slopes
Trisetum spicatum	Spiked False Oats	exposed
Sandplain / Open Meadow		
Asclepias verticillata	Linear-leaved Milkweed	open rocky
Eragrostis capillaris	Lace Love Grass	open sandy soil
Gentiana andrewsii	Andrew's Bottle Gentian	open/meadow
Liatris scariosa var novae-angliae	New England Blazing Star	sandy open pine wds.
Lupinus perennis	Wild Lupine	sandy open pine wds.
Paspalum setaceum	Paspalum	sandy soil
Penstemon hirsutus	Beard-Tongue	dry or rocky ground
Polygala verticillata	Whorled Milkwort	open woods/old field/stony shores
Aquatic Habitats		
Ponds / Streams		
Aster tradescantii	Tradescant's Aster	fields/swamps
Betula nigra	River Birch	swamps & stream banks
Cardamine longii	Long's Bitter-cress	swampy streams
Eleocharis intermedia	Intermediate Spikerush	exposed shores
Juncus filiformis	Thread Rush	meadows/springs/riverbank
Megalodonta beckii	Water Marigold	

Species	Common name	Comments
Myriophyllum alterniflorum	Alternate leaved Milfoil	
Nuphar pumila	Tiny Cow-Lily	
Panicum philadelphicum	Philadelphia Panic Grass	exposed shores
Scirpus ancistrochaetus	Barbed-bristle Bulrush	swales and shores
Sparganium angustifolium	Narrow-leaved Bur Weed	
Sparganium fluctuans	Bur-Reed	
Utricularia minor	Lesser Bladderwort	seepy stream sides
Utricularia resupinata	Bladderwort	swamps, swales, shores
Seeps/Seepage Areas		
Cardamine bulbosa	Spring Cress	
Conioselium chinense	Hemlock Parsley	black ash seepage swamps
Cypripedium calceolus v. parviflorum	Small Yellow Lady Slipper	black ash seepage swamps
Elatine americana	American Waterwort	wet clay soil
Mimulus moschatus	Muskflower	open seepage area
Pedicularis lanceolata	Lousewort	open areas
Platanthera flava var. herbiola	Pale Green Orchis	vernal streams in hardwoods
Stellaria borealis	Northern Stitchwort	
Trisetum pensylvanica	Swamp Oats	
Bogs/Boggy Areas		
Arceuthobium pusillum	Dwarf Mistletoe	grows on Black Spruce
Arethusa bulbosa	Arethusa	
Aster radula	Rough Aster	beaver meadows/swamp borders
Gentiana linearis	Narrow-leaved Gentian	boggy meadows
Scheuchzeria palustris	Pod Grass	
Smilacina trifolia	Three-leaved Solomon	boggy woods
Viola nephrophylla	Northern Bog Violet	
Xyris montana	Northern Yellow-eyed Grass	

2.6.2.3 Rare, Uncommon, and Exemplary Natural Communities

Natural communities have been defined in a variety of ways. Some definitions include only abiotic features, while other definitions rely primarily on the dominant vegetation of an area. Combining these approaches, natural communities can be defined as an assemblage of both biotic and physical conditions that occur together to form a functionally distinct area of the landscape. These unique assemblages caused by the combination of physical environment, biological interaction, and disturbance will dictate the type and extent of vegetation present, which in turn will shape the faunal community. The Quabbin watershed harbors a wide array of unique natural communities. Some of the communities are rare on a regional or global level. From 1997 to 2000, in response to a recommendation by the FSC forest certification auditor that the biological diversity at Quabbin should be better characterized, the University of Massachusetts Department of Natural Resources Conservation, under the primary direction of Associate Professor Kevin McGarigal, assessed the watershed for rare, uncommon, and exemplary natural communities. The purpose of this study is described in a September 2000 report entitled "Rare, Uncommon, and Exemplary Natural Communities of Quabbin Watershed": "to identify, classify, and describe the rare, unique, and exemplary natural communities in the Quabbin watershed area of Massachusetts and to provide recommendations for their management." The report identifies, and describes in detail, 22 rare communities in the Quabbin watershed. They include the following communities indicated by bold type:

TERRESTRIAL COMMUNITIES

- Terrestrial communities on exposed rock and shallow soils
  - Bedrock outcrops, summits, ridgetops and cliffs: ***Vaccinium* shrubland; *Juniperus virginiana* shrubland**
  - Talus slopes: **Talus slope community**
- Terrestrial communities on deep soils
  - Dry forests / well-drained soils
    - Sandy soils: ***Pinus rigida* - *Quercus ilicifolia* woodland**
  - Mesic forests / moderately well-drained soils
    - Sandy-loams to loams: ***Tsuga canadensis* -dominated forest**
    - Loams to silt-loams: ***Acer saccharum* - *Fraxinus americana* - *Tilia americana* forest**

RIPARIAN COMMUNITIES

- Streamside communities
  - High-gradient stream communities: ***Tsuga canadensis*-dominated stream community**
  - Low-gradient stream communities
    - Forest streamside communities: ***Tsuga canadensis*-dominated stream community**

PALUSTRINE COMMUNITIES

- Wetlands on mineral or muck soils
  - Basin and seepage wetlands
    - Temporarily flooded wetlands
      - Non-vegetated wetlands: **Vernal/autumnal pool**
      - Shrub swamps: **Kettlehole shrub swamp**
      - Forested swamps: ***Nyssa sylvatica* swamp; *Fraxinus nigra* swamp; *Picea mariana* swamp**
  - Fringe wetlands
    - Temporarily flooded wetlands
      - Forested swamps: ***Nyssa sylvatica* swamp; *Fraxinus nigra* swamp; *Picea mariana* swamp**
- Wetlands on peat
  - Basin and seepage peatlands
    - Herbaceous peatlands: **Poor fen**
    - Shrub peatlands: **Bog/acidic fen**
    - Forested peatlands: **Bog transition forest**
  - Fringe peatlands
    - Herbaceous peatlands: **Poor fen**
    - Shrub peatlands: **Bog/acidic fen**
    - Forested peatlands: **Bog transition forest**

The status of these communities at Quabbin and globally has been evaluated and is shown in **Table 31**.

Table 31: Status of Rare Communities on the Quabbin Reservoir Watershed

COMMUNITY	Global Status	Status at Quabbin	Threats
Terrestrial			
Vaccinium shrubland	Secure	Rare	Foot traffic, invasive plants
Red Cedar shrubland	Regionally rare	Rare	Foot traffic; invasive plants
Talus slope	Unknown	Uncommon	Disturbance above slope, invasive plants
Pitch Pine – Scrub Oak	Regionally rare	Rare	Fire suppression
Hemlock dominated forests	Unknown	Common	Hemlock wooly adelgid
Sugar Maple-White Ash-American Basswood forest	Secure	Uncommon	Invasive plants
Riparian			
Hemlock stream communities	Unknown	Common	Hemlock wooly adelgid
Palustrine			
Black Tupelo swamp	Very rare	Extremely rare	Beaver flooding; physical disturbance
Black Ash swamp	Very rare	Uncommon	Beaver flooding; physical disturbance
Black Spruce swamp	Uncommon	Uncommon	Beaver flooding; physical disturbance
Vernal pools	Unknown	Common	Disturbance to adjacent uplands
Peat, bog, fen, swamp shores	Very rare	Uncommon	Beaver flooding; invasive plants; trampling

Many of these rare communities are threatened to some extent by invasive plants or insects, as well as by pressures from increasing populations of native wildlife, such as beaver, deer, or moose. In some cases, watershed management activities have the potential to affect these areas positively or negatively. It is an abiding objective of DWSP to work to better understand these communities and to avoid negative impacts resulting from watershed management practices.

2.6.2.4 Rare Wildlife Species and Habitats

Division property within the Quabbin watershed is inhabited by a number of state-listed vertebrate species (**Table 32**). Rare species surveys often (and logically) focus on lands that are most actively threatened by development, rather than on large protected public holdings. The Division conducts general and some targeted surveys that discover new populations of listed species (plant and animal), but it is likely that there are undiscovered populations of rare and endangered species on Division property. Although land protection is the most critical factor for their survival, the Division recognizes the value in knowing where these species are located, in order to set priorities for specific protection measures and to guide management activities in or near critical habitats.

In order to ensure that land management activities do not disrupt or destroy listed species or their habitats, it is a Division objective to develop a more complete and current species occurrence database. DWSP's Natural Resources Section keeps records of listed plant and animal species on Division land that were discovered by in-house personnel or passed along by other professionals or the public. The MA Natural Heritage and Endangered Species program (NHESP) maintains more complete and detailed databases of listed species. Timber harvesting carried out by the Division is reviewed by a Service Forester, who

passes the cutting plan to NHESP when the harvesting map intersects a mapped Priority Habitat or Estimated Habitat for rare species (NHESP, 2006). NHESP sets restrictions on the harvesting activity if necessary to protect the species of concern. Routine maintenance (mowing, brush cutting) or watershed maintenance activities (road building/repair) are not required to file with NHESP. In these situations, it is possible to unknowingly and negatively impact rare or endangered species, but the Division is working to prevent this from happening through cooperation with NHESP to identify and map areas of concern that may be impacted. The Division is working with NHESP to improve staff awareness of rare species presence in order to prevent unintended impacts.

In many cases, rare and endangered species became rare because of loss of habitat or are further threatened by these losses. One of the greatest benefits of Division land to rare species is that it will remain undeveloped in perpetuity. As the majority of this land is covered by forest, it is of greatest benefit to rare or endangered species requiring forested habitat (sharp-shinned hawk, Cooper's hawk, Acadian flycatcher). Approximately half the species listed in **Table 32** are either dependent on wetlands or utilize them during some portion of their lives. Protecting and maintaining functioning wetland systems is a priority for the Division, which should benefit wetland species. In addition, vernal pools on Division land receive particular attention and protection (see section 5.2.5.7 and **Figure 18**). Further, current MA Conservation Management Practices (CMPs) for vernal pools have recently been revised to improve their effectiveness in protecting vernal pool dependent species.

Non-forested upland habitat is much rarer on Division property and is limited to maintained open spaces. There are several species on **Table 32** that require open fields or meadows. Although the Division will not create new field habitat, the importance of this habitat in the landscape is recognized. Therefore, where feasible, the Division will maintain and enhance this habitat where it exists on its land (see Section 5.5.5.4.1).

Areas with highly disturbed soils represent important habitat for several species listed in **Table 32**. On Division land there are several large active and inactive gravel and sand pits and areas of exposed stream banks and shoreline. Wood, Blanding's, and Box turtles use sandy or gravelly areas to lay their eggs. In addition, some invertebrates such as the Big Sand Tiger Beetle, Dune Ghost Tiger Beetle, Oblique-lined Tiger Beetle, Frosted Elfin, and Hoary Elfin utilize areas of highly disturbed soils. The Division recently documented Wood Turtles laying eggs in an abandoned Division sand pit. In many cases, however, these highly disturbed areas are scheduled for restoration (see Section 5.3.2.2). The Division recognizes the potential wildlife value some of these areas have, and in the future the Division will examine each site on a case-by-case basis to determine: 1) actual erosion threat, and 2) habitat suitability for selected wildlife species. In some cases, where erosion is not a threat, the site may be abandoned and left in its disturbed state.

Table 32: Status of State-listed Vertebrate Species whose Ranges Overlap DWSP Quabbin Properties

SPECIES	STATUS[1]	OCCURRENCE[2]
AMPHIBIANS		
Blue-Spotted Salamander	SC	Documented
Jefferson Salamander	SC	Documented
Marbled Salamander	T	Documented
Spring Salamander	SC	Documented
Four-Toed Salamander	SC	Documented
Eastern Spadefoot	T	Potential
REPTILES		
Spotted Turtle	SC	Documented
Wood Turtle	SC	Documented
Blanding's Turtle	T	Documented
Eastern Box Turtle	SC	Documented
Eastern Wormsnake	T	Potential
Eastern Ratsnake	E	Potential
Copperhead	E	Historic
Timber Rattlesnake	E	Historic
BIRDS[3]		
Common Loon	SC	Documented
Pied-Billed Grebe	E	Potential
American Bittern	E	Documented
Least Bittern	E	Documented
Bald Eagle	E	Documented
Northern Harrier	T	Potential
Sharp-Shinned Hawk	SC	Probable
Peregrine Falcon	E	Historic
King Rail	T	Potential
Common Moorhen	SC	Potential
Upland Sandpiper	E	Historic
Common Barn Owl	SC	Historic
Long-Eared Owl	SC	Probable
Short-Eared Owl	E	Historic
Sedge Wren	E	Historic
Golden-Winged Warbler	E	Probable
Vesper Sparrow	T	Probable
Grasshopper Sparrow	T	Probable
Henslow's Sparrow	E	Historic
MAMMALS		
Water Shrew	SC	Documented
Southern Bog Lemming	SC	Documented

[1] Species status in Massachusetts: SC= species documented to have suffered a decline that could threaten the species if allowed to continue unchecked; T = species likely to become endangered within the foreseeable future throughout all or a significant portion of its range; E = species in danger of extinction throughout all or a significant portion of its range.
[2] Occurrence of species on Division land within the watershed: Documented =species actually observed; Probable =species not documented, but given available habitat, species' range, and/or observations within the watershed, they are likely to occur; Potential =species not documented, and current habitat conditions may not be suitable, but with habitat enhancement they may occur; Historic= documented presence in the past, but has not recently been seen and may not be supported by current conditions.
[3] Occurrence of birds is limited to breeding pairs, not migratory or seasonal residents.

2.7 Quabbin Cultural Resources

Cultural Resources may be divided into four principal categories: historic records and documents, historic buildings and structures, historic or cultural landscapes, and archaeological resources (prehistoric and historic). Due to their varied nature, the many features and materials that can be classified as "cultural resources" at Quabbin require a multi-disciplinary management approach. Cultural Resources range from individual historical documents to artifacts of ordinary life during many centuries of human occupation of the Swift River Valley, to entire landscapes. In some cases, there is overlap between categories; for example, a stone wall is a construction but may also be a significant component of a cultural landscape. In many cases, there is room for interpretation and debate about the value of specific cultural resources and the importance or feasibility of preservation.

2.7.1 Records and Documents

Upon dissolution of the Swift River Valley towns prior to construction of the Reservoir, the Quabbin Superintendent became Town Clerk for Dana, Greenwich, Prescott and Enfield. Each Superintendent (now Regional Director) has held this office and has been responsible for maintaining the Vital Records of previous inhabitants of the Valley towns. Copies of these records are stored at the Quabbin Administration Building and are available to the public for research purposes. Similarly, the original survey "Taking Sheets," and photographs and records of each property purchased by the Commonwealth prior to the actual Reservoir construction, are archived in the Quabbin Engineering Office. For educational outreach purposes, DCR staff frequently draw upon in-house collections of artifacts as well as the extensive records of Reservoir construction and the early management of the watershed lands; including, for example, the development of a tree nursery and the establishment of plantations for water quality protection. In addition, an estimated 20,000 guests see educational displays at the Quabbin Visitor Center each year.

2.7.2 Buildings and Structures

There is a long history of human occupation and construction on Quabbin watershed lands (see Archaeology, below). DCR field staff, historians, area residents, and members of the Swift River Valley Historical Society continue to add to our knowledge and growing database of physical sites such as foundations, wells, mill sites, and cellar holes.

Between 1994 and 1998, a series of graduate students from the Department of Archaeology at Boston University created a "historical sites inventory" for the Quabbin watershed. The interns used a review of historical documentation (including the Quabbin "Taking Sheets," and 19th century Atlases) and information collected from foresters and local archaeological enthusiasts, to record 867 sites, many of which were visited in the field.* DCR staff digitized the site locations, and the presence and preservation of these features is included in planning for all forestry operations. Before any harvest takes place on a site or "lot," DCR Foresters circulate a detailed Lot Proposal for internal and public review. The Proposal includes information on cultural resources present on the proposed harvest site.

The following example of Cultural Resources identification and planned management action is taken from a Fiscal Year 2007 Lot Proposal:

> *Very nice cellar hole and associated walls on the Lot, right on the road. An interesting feature: the blown-down locust stand in the old pasture south of the cellar hole. These*

* Based on the original survey sheets, DCR subsequently digitized nearly one thousand additional historic site locations, most of which are now under water.

trees would have originated from sheep eating locust pods and depositing the seeds around the pasture. These large trees blew down in the 1938 Hurricane, suggesting that the area was abandoned as pasture well before the General Taking.

A forwarder will be used on the lot to minimize ground disturbance. (from Lot Proposal Form PE-07-10A, Steve Ward, DCR Forester)

In his review of Quabbin Lot Proposals for Fiscal Year 2007, DCR Archeologist Tom Mahlstedt subsequently identified this cellar hole as "the remains of the Benson Farmstead, which was occupied in the mid-1800s."

2.7.3 Landscapes and Landscape Features

A cultural landscape is defined as "a geographic area, including both cultural and natural resources and the wildlife or domestic animals therein, associated with a historic event, activity, or person or exhibiting other cultural or aesthetic values."* Cultural landscapes, sometimes called "heritage landscapes," include historic sites (such as battlefields), historic designed landscapes (such as estates and parks), historic vernacular landscapes (which can range in scale from a single farm to an industrial complex), and ethnographic landscapes (such as ceremonial grounds). These designations are not mutually exclusive.

These landscapes convey aspects of our shared history that forge our cultural identity. Heritage landscapes also reflect ecological and environmental conservation concerns, affect the real estate market, and attract tourism and recreation….Once we begin to look with an informed view, we see the wealth of knowledge that such landscapes convey about our community's past, the emotional connection many have to certain places, and how this awareness can improve our communities and our lives†

Charles A. Birnbaum, Landscape Architect for the National Park Service, writes of undertaking projects to ensure a successful balance between historic preservation and change: "Wise stewardship protects the character, and/or spirit of a place by recognizing history as change over time. Often, this also involves our own respectful changes through treatment."

2.7.3.1 Historical vernacular landscapes

Historical vernacular landscapes evolve through use by the people whose activities or occupancy shaped that landscape. Through social or cultural attitudes of an individual, family or a community, the landscape reflects the physical, biological, and cultural character of those everyday lives. Function plays a significant role in vernacular landscapes. They can be a single property, such as an orchard, or a collection of properties such as a district of historic farms along a river valley.‡ Examples include rural villages, industrial complexes, and agricultural landscapes.

Nearly all designed and vernacular landscapes evolve from, or are dependent on, natural resources. It is

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* This definition and much of the information on cultural landscapes is taken from: Birnbaum, Charles A. Preservation Brief 36: Protecting Cultural Landscapes: Planning, Treatment and Management of Historic Landscapes 1994 Technical Preservation Services, National Park Service, U.S. Department of the Interior.
† Reading the Land –Massachusetts Heritage Landscapes: A Guide to Identification and Protection, p6. DCR staff received the 2004 Public Education Award from the American Planning Association for publication of this Guide.
‡ Terra Firma 2: Putting Historic Landscape Preservation on Solid Ground. Massachusetts Department of Conservation and Recreation. 2006. Pg 3.

the dynamic qualities of these interconnected systems of land, air and water, vegetation and wildlife that differentiate cultural landscapes from other cultural resources, such as historic structures. However, such structures sometimes form a significant feature of a cultural landscape. The stone remains of mill sites found on the Quabbin watershed and throughout New England testify to the direct relationship between natural resources and the history of human land use in the region.*

Prior to the taking of land for the Quabbin Reservoir, much of the Swift River Valley was agricultural land – either pasturage or tillage. Since DCR has chosen managed forest cover to provide the most effective protection of the watershed and water supply, the earlier vernacular landscape has not been maintained or recreated on watershed lands. However, areas have been identified as representative of "primary forests" or "historical woodlots"; acreage that, even during the height of agricultural clearing, was retained as forest to provide timber and fuel, or simply because it was difficult or impossible to develop for agriculture.

2.7.3.2 Landscape Features

While a stewardship approach may be applied to an entire landscape, it can also be used to address a single feature, such as a perennial garden or a family burial plot. Within cultural landscapes, plants may have historical or botanical significance. A tree may have been associated with a historic figure or event or be part of a notable landscape design.† A plant or plant population may be an uncommon cultivar, exceptional in size or age, rare or commercially unavailable. In addition to their daily forest management responsibilities, DCR foresters selectively preserve historically and botanically significant plants and trees; for example, the occasional American Chestnut that has survived the Chestnut Blight to reach reproductive age or an ornamental planting of a native plant. Acorns from exceptionally productive oaks are collected and planted. A small apple orchard, struggling survivor of a now-vanished homestead, is given adequate care to enable its survival amidst more competitive vegetation, thus providing both a living reminder of the history of the area and a valuable source of food for Quabbin wildlife.

In general, historic roads across the Commonwealth are subject to public pressure for change, due to increased traffic volume, local construction and development, and related safety concerns.‡ In contrast, the land management strategy at Quabbin has effectively preserved a road and by-way pattern that developed over centuries of human land-use in the Swift River Valley, frequently highlighted by well-preserved stonewalls.

2.7.4 Archaeological Resources: Prehistoric

Archaeological evidence suggests that human occupation of the Swift River region may have been continuous for as long as 12,000 years. While evidence of this occupation has mostly been obscured by more recent land use, where such evidence remains, it is exceptionally precious for its link to the distant past.

2.7.4.1 Prehistoric Overview

Paleo Indian hunters and gatherers reached the Swift River drainage 9,500 to 12,000 years ago. Based on the presence of diagnostic Eastern fluted points in a local artifact collection, one northern Quabbin site has been tentatively identified as belonging to the Paleo Indian period. The site may have been near a

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* Paul Bigelow, Wrights and Privileges: the Mills and Shops of Pelham, Massachusetts, from 1740 to 1937, 1993, Haleys, Athol, MA.
† Terra Firma 2. p. 3.
‡ Terra Firma 3: Putting Historic Landscape Preservation on Solid Ground. Massachusetts Department of Conservation and Recreation. 2006. Pg 6-7.

glacial lake at a time when the landscape was changing from barren and tundra-like conditions to a spruce parkland-spruce woodland community (Davis 1969; Davis 1983).

By about 9,000 years ago the warming climate had created an environment in southern New England that supported a mixed pine-hardwood forest (Davis 1969; Davis 1983). Three archaeological sites along the Middle and East Branches of the Swift River indicate that human occupation of the northern Quabbin area continued during the Early Archaic period (ca. 9,500 to 8,000 years ago).

During the Middle Archaic period (ca. 8,000 - 6,000 years ago) the mixed deciduous forests of southern New England became established, and the present migratory patterns of many fish and birds may have developed (Dincauze 1974). Quabbin waterways utilized by anadromous fish for spawning may have led to seasonal fishing encampments of Native American groups; this was a subsistence strategy persisting throughout prehistory. Evidence of Native American occupation of the Quabbin region during Middle Archaic times comes from four sites, all of which were also occupied in earlier and/or later periods.

At least twenty-four sites within the Quabbin watershed have yielded diagnostic Late Archaic period materials. The marked increase in site frequencies and densities is consistent with findings throughout most of southern New England, and may reflect a population increase ca. 6,000 to 3,000 years ago. Each of the three traditions - the Laurentian, Susquehanna and Small Stemmed Traditions - is well represented in the archaeological record of local sites. Terminal Archaic activity (ca. 3,000 - 2,500 B.P.) is suggested at three sites, including a steatite (a type of soapstone) quarry.

Evidence of Native American occupation during the Early, Middle and Late Woodland periods (3,000 - 450 B.P.) comes from five Quabbin sites from each period. Regionally, horticulture was introduced during the Early Woodland period and small gardens may have been planted in clearings located on the fertile alluvial terraces next to the Swift River and its larger tributaries. Settlement is likely to have occurred on virtually any elevated, level and well-drained surface adjacent to a source of fresh water, including the headwaters of ephemeral streams, springs, and small wetlands and ponds. Rock shelters and other natural overhangs, and locations with southerly exposures, may also have been utilized.

2.7.4.2 Prehistoric Archaeological Interpretation

The cumulative archaeological evidence indicates that this portion of Massachusetts has been occupied more or less continuously since Paleo Indian times (ca. 12,000 - 9,000 years ago). Currently, the Massachusetts Historical Commission (MHC) has records for fifty prehistoric sites on Quabbin lands managed by the DCR Division of Water Supply Protection. Although the MHC's records are the most complete archaeological data bank in the state, these sites represent a 10,000-year span and therefore a great deal of sample error, and there is a strong likelihood that more sites remain undiscovered. All of the sites currently recorded in the Quabbin watershed were discovered by local artifact collectors exploring areas exposed when the waters of the reservoir were unusually low. Interior sites have yet to be explored.

Most of the known prehistoric sites in the former Swift River Valley and along its tributaries have been disturbed by subsequent human land-use. There is little substantive information regarding the formation processes and behavior responsible for creating these sites. Twenty-five of the fifty recorded sites within the Quabbin watershed are known by location only, with no indication of the type or range of artifacts and features that were encountered.

However, analysis of artifacts from the better-documented Quabbin sites reveals a pattern of multiple, recurrent occupation; few sites have yielded artifacts from a single cultural/temporal period. This suggests that recurrent, though intermittent occupation or utilization of a single site, sometimes over a period of several thousand years, may have been the prevalent pattern of prehistoric site development in this region. By analyzing the existing data in the context of current archaeological theory, predictions of

archaeologically sensitive areas and the expected type and range of prehistoric settlement in the Quabbin region have been formulated. The possibility of prehistoric site presence, based upon a model of topography and proximity to water, is one consideration in proposed silvicultural operations at Quabbin (see Section 5.6.1, Silviculture and Cultural Resource Management: Prehistoric Sites).

2.7.5 Archaeological Resources: Historic

European settlement in the Swift River Valley began in 1736, when the General Court made a grant of 1,000 acres of land for the Quabbin territory, and the development of both water-powered industries and agriculture began. The first church in the Swift River Valley was erected in Greenwich Plains in 1744, and Quabbin parish was incorporated in 1749. Shay's Rebellion occurred in 1787 and was plotted in Conkey's Tavern in what would eventually be incorporated as the town of Prescott. Greenwich was incorporated in 1754, Dana in 1801, Enfield in 1816, and Prescott in 1822. By 1822 the four towns had a combined population of about 3,000 (**Table 33**).

With the passage of the Swift River Act in 1927, the four valley towns were slated for disincorporation and their lands were purchased by the Commonwealth in the General Taking prior to construction of the Quabbin Reservoir. Together with additional land from adjacent towns, the state acquired a total of 80,433 acres by 1938, the official date of disincorporation of the four towns. During this time 650 houses and 450 other structures were removed from the Swift River Valley. Many buildings were relocated to other communities, in some cases as far away as Vermont. Some cellar holes were filled, leaving little or no trace of their existence, a practice that was particularly prevalent in Prescott.

Table 33: Population of Swift River Valley, 1830-1938

Date	Dana	Enfield	Greenwich	Prescott	Total
1830	623	1,056	813	758	3,250
1900	790	1,036	491	380	2,697
1920	599	790	399	236	2,024
1930	595	497	238	48	1,378
1935	387	495	219	18	1,119
1938	All four towns disincorporated				0

(Source: Quabbin Facts & Figures, published by the Friends of Quabbin, Inc. and the MDC, ca.1990)

2.7.5.1 Stone Walls

Perhaps the most common historic construction on the Quabbin landscape is the ubiquitous stone wall, lining the roads and tracing a far-flung pattern over hill and across valley. Often definable as both a construction and a cultural landscape component, stone walls are sometimes considered iconic; a rock-solid legacy of the earliest European settlers. This popular image has been challenged by Robert Thorson, a professor of geology and geophysics at the University of Connecticut. Thorson is a strong advocate for the preservation and informed appreciation of stone walls, but in his book, Stone By Stone: The Magnificent History in New England's Stone Walls, Thorson defines the construction of stone boundary walls as a late-18th to 20th-century undertaking, rather than a colonial occupation. He presents a pragmatic view: "However tidy well-built walls might appear, most functioned originally as linear landfills, built to hold nonbiodegradable agricultural refuse."* Also, contrary to the idea that preserving

* Thorson, p. 6.

stone walls is largely a matter of leaving them intact, Thorson asserts, "Left untended, every wall will come apart, tumble to the ground, disperse over acres of soil, and be buried by encroaching vegetation."*

In addition to their value as cultural resources and a link to the agricultural past, DWSP has funded their study by University of Massachusetts Landscape Ecologist Kevin McGarigal to determine the role of stone walls as wildlife habitat. In a report provided to the Division in 2000, Dr. McGarigal states the problem as follows:

> *The presumed ecological effects of stone walls are related to their distinctive linear structure and the spatial patterns these structural corridors impose on the broader landscape. Despite the clear impacts of stone walls and other linear features on the physical structure of the landscape, it is largely unclear whether stone walls function as corridors to affect landscape connectivity for organisms either by providing breeding habitat for individuals and thus serving to connect larger populations units by maintaining gene flow; by providing dispersal and/or migratory pathways and thus serving to facilitate movement of organisms among habitats; or by serving as barriers or filters that prevent or impede the movement of organisms across the corridor.*

At Quabbin, Dr. McGarigal studied vertebrate movements at specific locations in stone walls located in mature forests and captured 18 separate animal species using the walls as habitat. The movement and breeding of small mammals seemed to be facilitated by the cover provided by stonewalls, while amphibians and reptiles seem to simply move through the walls on their way to breeding habitats.

Stone walls are offered some protection by State law in Massachusetts. Ch. 40, Section 15C requires a public hearing process before stone walls can be removed or destroyed on any road designated as a "scenic road." They are protected as "property" against destruction or removal (Ch. 266, Section 105) and as "natural scenery" against defacement (Ch. 266, Sections 126 and 126B). The latter applies not only to stones and stone walls, but also to gravestones, buildings, walls, monuments; in effect, the favorite targets of graffiti "artists." Where stone walls are part of a dam, waterway or mill site, they may also be protected under Ch. 266, Section 138, which addresses "malicious injury" to dams and reservoirs. DWSP affords protection for historic features both to meet statutory obligations and out of respect for the displaced former residents whose families once called these areas home. Efforts are currently underway to improve the mapping and general awareness of stone walls on the Quabbin landscape.

2.7.5.2 Wells and Cellar Holes

Unlike the miles of stone walls apparent throughout the Quabbin watershed, many constructed features are discovered only by stumbling upon them – sometimes literally, as in the unfortunate example of wells which are often found when a walker's foot suddenly drops straight down into a deep, narrow hole made invisible by an accumulation of forest debris. Although stone foundations, wells, and cellar holes often occur in obvious locations, there are examples in remote and relatively inaccessible places that would only be found by coming across them unexpectedly. Because DCR Foresters walk every square mile of managed forest in the course of their duties at Quabbin, they are the most likely to discover and identify these features. GPS technology provides the possibility of pinpointing these features as they are discovered.

* Thorson, p. 9.

3 Principles Guiding Watershed Management

The science of watershed management continues to evolve, although many basic principles have been long-established and are now widely accepted as the basis for informed management. It is the intent of the Division to constantly review the literature and stay on top of research developments that impact management decisions. The purpose of this section is to describe current principles in the general areas of watershed protection, water yield and quality maintenance, the value of forest cover for water protection, the impact of a wide variety of disturbances on the delivery of high quality water from forested watersheds, and the role of active management in developing resistance and resilience in the water supply protection forest.

3.1 General Watershed Management Principles

3.1.1 Watershed Protection

- Forested watersheds generally yield higher quality water than non-forested cover types. Most urban, suburban and agricultural land uses contribute in some way to lowered water quality.

- Uncontrolled human activities on water supply watersheds represent a major source of potential contamination. Efficient and effective water quality protection on both filtered and unfiltered water supplies requires control over human activities.

- Watershed cover conditions differ in their regulation of certain nutrients (e.g., nitrates, phosphates). Within the variety of watershed land cover types, the best regulation of nutrients is provided by maintaining vigorously growing forest across the vast majority of watershed sites. Forests developed through silvicultural methods that include the range from single-tree to small group and patch regeneration cutting will include a range of size and age classes, as well as a mix of species across the continuum from shade tolerant to shade intolerant.

- Fire protection, watershed ranger and police surveillance, water sampling, and other watershed management activities, including forest management, all depend upon an adequate, well-maintained watershed road system. Poorly designed or inadequately maintained roads represent the greatest potential source of sediment inputs to tributaries on undeveloped watersheds.

- The proper management and protection of wetland and riparian zones is a critical component of watershed protection, in part because these frequently are concentrated water supply source areas and because they represent the final opportunity to capture mobile sediments/nutrients before they enter surface waters.

3.1.2 Water Yield

- Water yields are influenced by precipitation amounts, site conditions (such as slope, aspect, and soils) and the intensity and type of watershed cover management.

- Water yields are affected directly by evapotranspiration rates of the watershed cover. Therefore, management activities that result in decreased evapotranspiration also result in increased water yield, while those that increase evapotranspiration decrease water yield.

- Intensive, even-aged management of forested watersheds provides consistently greater water yields than uneven-aged management, multi-aged management or the absence of active management.

- Water yields decrease as young forests grow. As forests become more open, water yields increase. When watershed forests are disturbed, water yields initially increase. As disturbed areas fill with young forests, water yields decrease.

- Paired watershed experiments across many regions have demonstrated that until approximately 20-30% of the forest is cut, there is generally no measurable increase in water yield, and furthermore that water yield generally returns to or below the pre harvest baseline within 3-10 years unless there is a significant change in species composition (e.g., from deciduous species to evergreens), in which case some degree of change in yield will persist indefinitely.

3.1.3 Water Quality

- Surface waters collected from fully vegetated watersheds with minimal exposed soils generally carry very low turbidity.

- Bacteria counts in surface waters may or may not be buffered by vegetated land cover, depending on the sources of bacteria present and their contact with these waters.

- Critical protection of water quality for predominantly forested and actively managed watersheds includes the following principles:
  - Minimizing land use/land cover changes in order to maintain forest cover across the majority of the watershed provides the most effective primary barrier for protecting tributary and reservoir water from pollutants.
  - In actively managed forests, Conservation Management Practices, correctly designed and applied effectively will protect water sources from sediment/nutrient losses otherwise associated with forest management activities.
  - The most common sources of water quality degradation by timber harvesting are intersections between harvesting roads or staging areas and water sources. Disconnecting roads/staging areas from water sources prevents water quality degradation.
  - To prevent contamination of surface and ground waters, petroleum products on water supply watersheds must be tightly contained or replaced with biodegradable alternatives.
  - Maintaining a species and age/size-diverse forest cover may increase that cover's resistance to disturbance and ability to recover quickly when disturbance occurs. Active management can increase size and species diversity where past land use or natural disturbances have homogenized the forest cover.

3.1.4 Unfiltered Water Supply Regulatory Requirements

Unfiltered surface water supplies are mainly regulated under two EPA promulgated rules: the Long Term Surface Water Treatment Rule (LT2) and the Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2). Both rules were released by EPA in January, 2006.

In order to maintain its status as an unfiltered water supply system, the Quabbin Reservoir must meet the main aspects of the LT2, which are:

- Non-filtered water supplies must maintain a watershed control program. A well managed forestry program is an integral part of any watershed management program.

- Turbidity levels must not exceed 5 Nephelometric Turbidity Units (NTU). A well managed forest over the watershed prevents erosion and ensures that turbidity levels as measured at the CVA average under 0.5 NTU.

- Fecal coliform concentrations must be less 20/100 ml prior to disinfection in 90% of samples taken during any consecutive six month period. At Quabbin, MWRA meets all regulatory standards although the source water criteria require the implementation of an active seagull harassment program starting in late full and often through early spring.

- MWRA will be required to conduct two years of source water monitoring at Quabbin for the presence of *Cryptosporidium* oocysts. All the results will be averaged, and if the mean is less than 0.01 oocysts/L, MWRA will be required to provide at least 2-log *Cryptosporidium* inactivation. If the mean is greater than 0.01 oocysts/L, MWRA will then be required to provide at least 3-log *Cryptosporidium* inactivation. Based on data collected over several years indicate that the mean will most likely be less than 0.01 oocysts/L (Lasky, 2006). The existence of an active beaver and muskrat exclusion program over the Pathogen Free Zone on the Winsor Dam Basin is one of the main reasons for the low mean.

- In order to meet the water quality standards of Stage 2, source water has to meet the following standards with regard to disinfection by-products (DBPs): Average maximum contaminant levels (MCLs) for trihalomethane (THM) of 80 parts per billion (ppb) and 60 ppb for haloacetic acid (HAA). Current levels are in the 4 – 12 ppb range for both. The following is background information on DBPs (Garvey *et al.*., 2001):

  - DBPs are formed by reactions between oxidants, usually chlorine based, and organic compounds.

  - Natural organic matter (NOM) in the water is composed of both dissolved and particulate organic substances, and can originate on land (allochthonous) or within the aquatic system (autochthonous).

  - NOM is measured as total organic carbon (TOC). TOC is composed of dissolved organic carbon (DOC) and of particulate organic carbon (POC). DOC normally accounts for approximately 90% of TOC. DOC can be a precursor for DBPs.

  - Planktonic algae account for the most significant percentage of autochthonous inputs. Most DOC in Quabbin is autochthonous.

  - DOC is directly related to the eutrophic state of a water body. Eutrophication is related to the amount of nutrients, mainly nitrogen and phosphorous, available for algal growth, with phosphorous usually the most limiting. Eutrophication is driven by external loading of organic matter, nutrients and silt. A well managed, forested watershed sequesters nutrients.

3.2 Basic Principles of Forest Hydrology

Hydrology is the scientific study of the liquid and frozen waters of the earth, their properties, circulation, and distribution on and under the Earth's surface and in the atmosphere, from the moment of precipitation until these waters are returned to the atmosphere through evapotranspiration or are discharged into the ocean. Forest hydrology is more specifically the study of the circulation of water into and through forested lands, and details the effects of the forest on water at scales ranging from a single tree to a partially or fully forested watershed. Among the most critical investigations in forest hydrology is the impact of the forest on water yield, the difference in the amount of water that arrives from the atmosphere via precipitation and the amount that ultimately leaves the watershed via draining tributaries. Increasingly, as drinking water supplies become more critically limiting, the relationship between forest cover and water quality has become a central topic in forest hydrology, in part because of the links between water yield and the yield of sediments and nutrients to water supplies.

3.2.1 Forests and Water Yield

- Evergreens (generally conifers) use more water than deciduous species over the course of a year, in part because they continue to transpire after deciduous trees have dropped their leaves.

- Generally, where precipitation exceeds potential evapotranspiration (PET = the amount of water that could be removed by a crop of short vegetation in given conditions of heat and wind energy), forests can grow. Where forests are removed in whole or in part from these areas, actual ET decreases and yield increases. The water balance is generally expressed as P – ET – Q +/- change in S +/- L = 0, where P=precipitation; ET=evapotranspiration; Q= water yield; S=storage, and L=leakage. Decades of forest hydrology research have shown that for many forests, removal of forest cover must reach 20-30% before increased yields are detectable.

- As much as 20-30% of rain and snow falling on a given forest is intercepted by forest cover, and a portion of this evaporates before reaching the ground, a portion runs down the leaves, branches, and stems to reach the ground, and a portion accumulates to larger drops and falls toward the ground from the canopy.

3.2.2 Forests and Water Quality

- No other land cover has been shown to protect the quality of drinking water better than forest cover.

- The accumulation of organic matter, the growth of fine and coarse roots, the actions of soil-dwelling microbes, invertebrates and vertebrates, and other natural processes develop properties of infiltration, hydraulic conductivity, and water storage (porosity) that are unique to forest soils and contribute to the protection of water quality.

- The interception of rain by forests modulates its kinetic energy, reducing its ability to dislodge soil particles and cause erosion. However, a raindrop can regain terminal velocity in approximately 60 feet (Chang, 2003), so it is the vegetation beneath the forest canopy and the accumulation of organic materials on the forest floor that provides the greatest assurance of reducing the erosive energy of rain (Stuart and Edwards, 2006).

3.3 The Value of Forests in Protecting Drinking Water Supplies

Water arrives in the watersheds that supply cities and towns of Massachusetts as precipitation in all of its forms, in annual amounts averaging 44 inches of rain, and carrying a wide range of airborne pollutants acquired when water droplets form around atmospheric particulates and when condensing clouds dissolve atmospheric gasses, producing sulphur dioxide, nitrous oxides, ozone, and ammonia. It leaves these watersheds, to enter the drinking water supply systems, after traveling a path ranging from direct to torturous, through land cover ranging from pavement to dense forest, and after a time period ranging from minutes to years. In a forested watershed, the erosive energy of even the most driving rainfall is absorbed and the relatively long path and timeframe from precipitation to the tap purges pollutants, minimizes erosion of sediments and nutrients, and delivers high quality raw water.

There are exceptions to this general rule, e.g., when forest-based wildlife carries pathogens of human consequence to the watercourse. In general, however, there simply is no other watershed cover or land use that exceeds the purifying role of forests for protecting drinking water supplies nor that provides this protection more reliably, through the wide range of weather and climate extremes from severe drought to extreme rainfall events. Forested watersheds supply this unparalleled drinking water protection and can simultaneously deliver undeveloped open space and its associated values, protection for both rare and common species and their habitats, and renewable, sustainable wood production that supports rural economies and reduces dependence on long-distance transportation of natural resources.

The interactions of the components of the protective buffering provided by forest cover are complex, but include at least the following:

- The forest canopy intercepts precipitation before it reaches the forest floor, initially removing some pollutants (e.g., through denitrification), and reducing the velocity of raindrops before they reach potentially erodible soils.

- The midstory and understory vegetation further reduce the kinetic energy of falling rain, passing it more gently to the forest floor, and also aggressively capture mobile, inorganic nutrients from the soil water as they grow and accumulate biomass.

- From the point in time at which it is regenerated, a typical stand of trees in a northern temperate forest continues to accumulate biomass, first quite rapidly and then more gradually, until about year 50-60 (Bormann and Likens, 1979b). Beyond this point, the ratio of respiratory to photosynthetic tissues increases, so that net accumulations slow.

- The infiltration rates of forest soils, with high contents of organic materials, and porosity maintained by burrowing fauna and the penetration and decay of roots of all sizes, are seldom exceeded by the rainfall rates of precipitation events, so that overland flow and its associated delivery of sediments is an exceedingly rare event on fully forested watersheds. Even where 'hardpan' layers of soil exist within the forest soil profile, the result is generally lateral interflow rather than overland flow.

- Surface litter on the forest floor presents a Manning's coefficient (the roughness, or resistance to overland water flow) of approximately 0.4, and, where forest understory vegetation is dense, the coefficient can reach 0.8, in sharp contrast to the resistance provided by asphalt (0.012) or even dense turf (0.35) (Novotny, 2003) further reducing the surface transport of sediments and nutrients.

- Even following a major loss of overstory, e.g., resulting from a catastrophic storm event, the

dense organic matter of the fallen forest continues to resist erosion of particulate matter, and, so long as regeneration capacity is not restricted, rapidly regains control over mobilized nutrients (Bormann, et al., 1974; Foster, et al., 1997). This condition may be enhanced or diminished by active forest management, depending on a wide variety of factors.

- Thick organic soils support microbial denitrification (the conversion of nitrate, a potential water pollutant, to nitrogen gas) which represents a loss of inorganic nitrogen to forest vegetation, but also prevents excesses of that mobile nutrient from entering water sources.

- For partially forested watersheds, in which sources of pollutants exist up gradient from forested sections, biological remediation in forested systems can effectively filter and reduce potentially toxic components such as heavy metals (Chen and Cutright, 2003; Pulford and Watson, 2002; French et al., 2006), pesticides (Arora, et al., 1996; Paterson and Schnoor, 1992), and nitrogen in wastewater (Aronsson and Perttu, 2001) or from agricultural sources (Mayer, et al., 2006).and a wide variety of organic pollutants (Aiken, et al., 1991).

The protection provided by forest cover functions at every scale, from the individual tree, to a forest stand (by definition, relatively homogeneous in composition and structure), and most importantly, on the landscape scale of a relatively more diverse forested watershed.

An individual tree serves to capture and slow precipitation, processes pollutants through both mechanical trapping (http://www.sussex.ac.uk/press_office/media/media12.html) and biochemical processing (http://aehsmag.com/issues/2001/june_july/bioremediation.htm), and buffers against local soil saturation through passive interception and evaporation and active transpiration (collectively, 'evapotranspiration'). When rain falls on an individual tree, a significant portion of that rain is intercepted by leaves, branches, and/or the trunk of the tree (when the rain falls as snow, an even greater proportion is intercepted, especially by evergreens). An individual rain drop may be held until it is evaporated (approximately 10-15% of rainfall), it may simply run down the trunk of the tree to the ground (~5%), or it may drop to the forest floor directly, often after coalescing with other raindrops, or simply fall through gaps in the trees cover. While trees serve to break the fall of raindrops, these drops can regain terminal velocity within about 60 feet (Chang, 2003), so that a groundcover of plants and young trees and/or layers of accumulated organic materials are necessary to limit the erosive power of rain on the soils beneath a maturing forest.

While many factors determine evapotranspiration rates, a mature, open-grown deciduous tree is estimated to have in excess of 200,000 leaves, which, on a summer day, can transpire as much as 900 gallons of water (DeCoster and Herrington, 1988). The evapotranspiration associated with an individual tree limits the frequency with which the soils it occupies become saturated, thereby maintaining infiltration and limiting overland flow of water and the associated transport of nutrients and sediments. In addition, trees directly process pollutants in a variety of beneficial ways. Some airborne pollutants are simply trapped on the surfaces of the tree, removing them from the ambient air and temporarily stalling their entry to the water system. Biochemical reduction of pollutants by plants (the basis of "bioremediation") is a varied and complex combination of processes that includes: improved degradation by soil microorganisms through rhizosphere enhancement (primarily nutrient additions); the uptake, translocation, and volatilization of unmetabolized compounds; and the uptake and metabolism or storage of other compounds (http//www.cpeo.org/techtree/ttdescript/phytrem.htm) . So long as pollutant levels are not toxic to the trees, these processes clean the water that moves through the forest.

In addition to these direct influences on water quality, individual trees also: anchor soil; produce soil macropores as roots penetrate and die, increasing infiltration capacity and reducing overland flow; capture and utilize inorganic nutrients in the soil for growth and metabolism; provide shade that regulates decomposition processes and the temperature of streams; deliver organic materials (leaves, twigs) to the

forest floor, thus reducing erosion; and produce seed that enhances the forest's ability to recover from disturbances.

A forest stand protects water supplies through the multiplication of the effects of individual trees and understory plants, but also provides collective effects that go beyond those of individual plants. When an individual tree in a stand matures and begins to decline, it also begins to lose its ability to affect water quality. Leaf area, transpiration, root penetration, growth and nutrient uptake, shade, and eventually seed production all decline. This process may result from simple stem exclusion, through which an initial stand of perhaps a million seedlings per acre is reduced by competition to a mature forest of 100-200 trees. Or it may result from a large array of defoliators, fungi, or viruses, or from injuries following wind or ice storms. Regardless of the cause, the influence of a forest stand is that the living, thriving trees surrounding a tree in decline will utilize the resources made available by the dying tree, including sunlight, water, and nutrients, and the result for water quality is uninterrupted protection. When a disturbance forces groups of trees into rapid or gradual decline, the protection provided by the stand relies upon regeneration to replace the functions of the dying trees, rather than upon surrounding, vigorous trees.

Stand types (roughly homogeneous combination of species and age classes) produce categorically similar effects on water quantity. Evergreen conifer stands generally reduce water yield below that produced by deciduous trees on similar sites, primarily because evergreens continue transpiring throughout the year and because they intercept a higher percentage of snowfall, a portion of which either evaporates or directly sublimates. Stand age affects water quality, also in roughly predictable ways. Young, established stands of any species mix are accumulating biomass more rapidly than older, maturing stands, and therefore assimilating available nutrients more aggressively due to higher biotic demand for these nutrients (Bormann and Likens, 1979; Vitousek and Reiners, 1975). As expected, this demand is highest during the growing season, which is reflected in the seasonal patterns of nutrient flux. As decomposition and respiration rates begin to balance or exceed the rate of primary production, the capacity for nutrient assimilation by older stands begins to decline. Although nutrients are still held tightly by older stands, outside additions (e.g., atmospheric transport of nitrous oxides) can overwhelm this assimilation capacity and result in leaching and hydrologic losses, and long-standing accumulations of organics can lead to higher losses of organic forms of nutrients to adjacent waters (Hedin, et al., 1995).

The forested watershed accumulates the effects of individual trees and forest stands to provide highly resilient protection for drinking water supplies. Even after intense land use practices have pushed the forest toward homogeneity, the range of seed sources, topographic positions, water regimes, aspects, soil types, and bedrock composition conspire to maintain a diversity of stand types. The mix of types across the watershed at any given time produces a predictable yield, a predictable volume of water delivered to the reservoir or river system, while the inherent diversity in species composition provides the watershed forest with a level of redundancy in maintaining itself that rivals the most responsibly engineered water treatment plant. The diverse structure in the living green filter across the watershed, like diversity in an investment portfolio, yields more consistent performance through the vagaries of climate fluctuations, wind, snow, and ice, rainfall intensity, and damaging native and alien pests than a forest (or an artificial filter) built to a single design. The range in structural and species composition across the forested watershed represents built-in multiple barriers, providing a forest biofilter that functions 24 hours a day on free solar energy (Barten, 2006)

3.4 The Effects of Disturbance on the Watershed Protection Forest

3.4.1 General Types, Frequency, and Principles of Disturbance

Disturbances can be broadly categorized as *endogenous* (autogenic, originating within the ecological community, e.g., through the death and subsequent fall of a single large tree) or *exogenous* (allogenic, originating from forces outside the ecological community, e.g., wind thrown trees that occur as a direct result of catastrophic tropical storms) (Attiwill, 1994a; Bormann and Likens, 1979). Endogenous disturbances generally remain localized and pose minimal threats to water supplies, while exogenous disturbances can create either chronic or catastrophic landscape scale changes that may result in direct or indirect effects on these supplies. Attiwill (1994b) addressed the ability of a forest ecosystem to respond to disturbance in terms of *resistance* (factors which delay or prevent movement from a pre-disturbance state to a disturbed state) and *resilience* (the ability to return quickly to the pre-disturbance state).

There is a significant body of literature regarding the use of natural disturbances as a model for regulating the pace and design of silviculture and timber harvesting, driven in part by concerns for long-term sustainability (Attiwill, 1994b; Armstrong, 1999; Franklin et al., 2002; Larsen and Johnson, 1998; Roberts and Gilliam, 1995). Runkle (1985) calculated that on average, between major disturbances, regular, endogenous disturbances regenerate 0.5% to 2.0% of the temperate forest annually, suggesting that the natural forest is well adapted to deliberate silviculture that occurs at this rate. In the context of water supply forestry, these concepts may or may not be critical, depending on the objectives for the property and the intensity of silviculture that is possible. It is critical, on the other hand, to understand the temporal and spatial scales of natural disturbances for any given water supply protection forest, in order to design silvicultural treatments that work within this context to retain or increase resistance and resilience in that forest.

A recent "microburst" disturbance.

That the forests surrounding the Quabbin Reservoir will be regularly and at times catastrophically disturbed is without question. Throughout its past and recent history, this forest has been repeatedly visited by: snow and ice storms; strong winds that accompany thunderstorms, nor'easter's, microbursts, or hurricanes; occasional fires; intense precipitation events; chronic environmental changes such as air pollution or global warming; and a very broad spectrum of both native and alien insects and diseases. The estimated background level of endogenous disturbance for forests in this region of about 0.5% - 2.0% of the forest area annually, in part accounts for the relatively uncommon presence of trees or stands that have persisted for longer than 100-200 years (where such older trees or stands persist, they provide a valuable component of landscape-level biodiversity and may contribute important genetic diversity as well).

The science of forest disturbance and response is complex. The following are some generalized principles, from the disturbance literature:

- Overstory wind throw, in the absence of rapid regeneration, can temporarily increase erosion and nutrient leaching, by disturbing soils, increasing decomposition rates, and causing a setback in biomass accumulation rates.

- Severe forest fires can significantly reduce soil infiltration, thereby increasing overland flow of water, sediments, organic materials, and nutrients.

- A forest that is diverse in age structure and species composition limits the impacts of age- and species-specific disturbances.

- Forests with advance tree regeneration in the understory will recover more quickly from disturbances to the forest overstory than will forests with poor understory development.

- Younger, shorter trees will sustain less damage from severe windstorms than taller, older trees, due both to their lower tendency to "catch" the wind, and to stem flexibility.

- While tightly grown, aerodynamically smooth *stands* may deflect wind better than those that are aerodynamically rough, *individual trees* that have been grown in more open stands will develop strongly tapered stems that resist wind better than the non-tapered stems of trees grown in tight stands.

- Saturated overland flow from infrequent, large storms with intense rains and rapid spring snowmelt account for much of the annual particulate, sediment, and dissolved nutrient outputs from watersheds in any given year.

3.4.2 Specific Disturbances

3.4.2.1 Weather Events

There are many ways in which weather affects the growth and development of the watershed protection forest and in turn can affect quality and quantity of associated water resources, the most common are ice and heavy (wet) snow, wind (hurricanes, microbursts, intense thunderstorms, tornadoes), large accumulations of snow followed by rapid snowmelt, intense precipitation, lightning, and long periods of drought.

3.4.2.1.1 Ice or Heavy Snow Build-up

Ice or heavy snow build-up, caused by a variety of weather anomalies that are becoming more common as average winter temperatures rise, puts excessive weight on branches and eventually on stems, causing breakage that weakens or kills the tree. Conifers that dominate northern snowy regions have evolved a conical shape that sheds most snows successfully, without lasting damage, but the weight and tenacity of wet snow and ice can exceed even this adaptation. The most common cause for ice build-up is the melting of snow falling from higher, colder air masses as it passes through a warm layer of air before hitting forest canopy, where it refreezes and accumulates as ice. The ice storm of January 1998 was among the most extensive of these in recent history, covering a large area north and east of Lake Ontario, and depositing ice as thick as 4", leading to massive loss of limbs and trees.

While these storms can be devastating set backs in the growth of trees and the production of everything from maple syrup to sawlogs, their impacts on drinking water supply may be less obvious. Hooper, et al., (2001) quantified the effects of the storm of 1998 and calculated that 33.6 cubic meters of woody debris was created by the loss of approximately 10% of the above-ground biomass in the forests of Quebec. This overstory reduction likely also resulted in an increase in decomposition rates and nitrification/ mineralization rates, as well as a loss of evapotranspiration during the period from the storm until both the surviving overstory and the understory recovered. The massive additions of coarse and fine woody debris

to the forest floor would have prevented erosion from heavy precipitation, but the losses of evapotranspiration could result in higher water yields and the associated movement of nutrients from the forest and of stream deposits due to more frequent high flows and related bank erosion.

3.4.2.1.2 Wind

Wind is a constant component of the watershed forest and its effects have been widely studied. Trees have adapted to this ever-present force, much as conifers have adapted to the presence of snow. Tree crowns and stems are flexible and can bend sharply without breaking. Tree, branch, and even leaf structure allow the crowns to fold into an aerodynamic and compact form during average wind storms, without damage. For example, sugar maples with crown widths of 5-6m on a calm day have been observed to contract to 2m widths in storms of 110-120 km/h (Frelich, 2002) and conifers can reduce their surface area by 45% in winds of as little as 40 km/h (Banks, 1973).

There are limits to the resiliency of individual trees. Trees in dense stands may rely on the support of adjacent trees to overcome their otherwise wind-susceptible form, with small root masses and minimal stem taper, compared to open-grown trees in well-thinned stands. The risk in opening these stands is determined by the return interval of wind disturbance versus the thinning response time required for the residual trees to develop wind-resistant taper and root mass, both of which are difficult to predict accurately. Each species and size-class has a maximum sustainable wind speed. For sitka spruce this critical wind speed for tree failure has been calculated as 184 km/h for 18 m tall plantations with 3 m spacing (Blackburn and Petty, 1988). In addition to stand density, wind damage to individual trees is related to height (winds are stronger at greater heights above the ground) and trunk size (larger diameter trees have stiffer stems, which reduces their susceptibility to breakage, but increases the transfer of canopy wind force to the roots, where it can result in root failure and then toppling of the tree (Frelich, 2002; King, 1986)). Finally, age can affect the susceptibility of trees to wind damage simply because the likelihood of stem rot from a wide variety of sources increases with age (Frelich, 2002).

Occasional losses of individual or small groups of trees due to wind are not generally a problem for water supplies. The potential water quality effects of catastrophic winds that damage large areas of the watershed forest are variable, but may present risks. The loss of a block of trees on a stable site that is not adjacent to the water supply may result in only gradual, relatively minor adjustments to ecosystem processes, including nutrient losses from the site (Foster, et al., 1997). However, the uprooting of streamside canopy trees by hurricane force winds can result in a four-fold increase in groundwater nitrate and a doubling of stream water nitrate (Yeakley, et al., 2003). The impact on the forest canopy from catastrophic wind events was documented following the hurricane of 1938, by researchers at the Harvard Forest in Petersham, MA. On level or windward slopes, >75% of softwoods greater than 34 feet and hardwoods greater than 74 feet tall were damaged, and the landscape pattern of disturbance ranges from individual trees to areas as large as 35 ha (Foster and Boose, 1992). Depending on the saturation level of the forest soils and the type of trees affected, catastrophic winds may either break stems and branches or uproot whole trees. The later presents the possibility of moving exposed soils in subsequent or concurrent rain events, although intact surrounding forest floor would likely mitigate this affect.

Hurricanes have passed through the Quabbin forest every 20-40 years, although catastrophic storms (Category III or higher with winds above 110 mph; the Hurricane of 1938 had winds of 120 mph) have historically occurred just once every 100-150 years (Foster, 1988b). The most recent hurricanes to make landfall in the region as Category 1 or higher hurricanes were Gloria (1985) and Bob (1991). Hurricane Floyd (1999) weakened to a tropical storm before making landfall in New England.

Some wind events of concern are not as wide as hurricanes but may include stronger winds. Tornadoes (winds from 40 mph (F0) to 318 mph (F5), and widths 300 ft to 6,500 ft) or microbursts (downdraft winds with a horizontal extent of less than 2.5 miles but with winds approaching 170 mph) can cause extensive

damage to limited blocks of the forest. While climate changes may increase their frequency, Massachusetts typically receives 2 or fewer observed tornadoes annually (compared, at the other extreme, to 100-180 per year in Texas). Among the most damaging recent tornadoes in Massachusetts was the Great Barrington Memorial Day tornado of 1995, an F4 tornado (wind speeds from 207 to 260 mph) that caused 3 fatalities and 23 injuries and did extensive damage to forests and structures in its path. While they are uncommon in Massachusetts, the straight-line, destructive windstorm referred to as a "derecho" can reach wind speeds well in excess of 100 miles and persist for long distances as clustered downbursts associated with a rapidly moving band of thunderstorms (Frelich, 2002). At least three such storms have been recorded in Massachusetts since 1995 (http://www.spc.noaa.gov/misc/AbtDerechos/derechofacts.htm#historic).

3.4.2.1.3 Rapid Snowmelt and Intense Precipitation

Rapid snowmelt and intense precipitation share some common effects on the water supply. Both can overwhelm infiltration rates even when storage capacity by detention (large pores filled by gravity) and retention (small pores in which water is held against gravity by capillary or matric, adsorptive forces) in forest soils is still available. The result is high peak flows in the hydrograph, which often correlates to bank scouring and erosion of sediments and nutrients. It has been shown repeatedly in the Northeast that a very few high intensity storm and snowmelt events are responsible for the vast majority of the annual transport of sediments by any given stream.

3.4.2.1.4 Lightning

The effects of lightning on the watershed protection forest are generally of limited scale, often resulting in damage only to a single unfortunately positioned tree. It is not uncommon to see tall, dominant white pine trees in the Quabbin forest that have been struck by lightning, leaving a spiraling split in the bark from the top of the tree to the ground. This wound may heal over, but often it is the site for further damage to the tree as insects or diseases take advantage of the break in the tree's defense. However, the loss of individual trees does not threaten water supply. An uncommon but potentially greater impact occurs when lightning strikes during a dry period and ignites a fire. There have been few incidences of this combination within the Quabbin forest during its history as a water supply protection forest.

3.4.2.1.5 Drought

Drought may not have direct consequences on the water supply other than the obvious reduction in yields. Severe droughts can cause mortality in the understory and overstory vegetation, but it is extremely uncommon for this to be extensive. More common are fires that follow long dry periods. The effects of fire on the watershed protection forest are reviewed separately in Section 3.4.2.2.

3.4.2.2 Fire

Fires in the conifer-dominated western U.S. have been shown to cause problems for water quality (Beschta, 1990), depending on the severity of the fire, the timing of following precipitation events, and the biogeochemistry of the region of the fire (Dissmeyer, 2000). Catastrophic wildfire is less common in the broadleaf forests of northeastern U.S. in modern times, in part because of suppression efforts but also due to the generally higher moisture content of trees and understory of the region during the growing season. Fires that do occur in these forests are frequently set by careless human activity and are most likely to occur when the snow is off the ground and leaves are off the trees.

Most fires in the Quabbin forest in recent years have been set by humans and confined to areas of less than 10 acres. They have been primarily low, ground fires that burn surface organic material and small trees and shrubs, but do not kill or move to the crowns of larger trees. There have been exceptions, including two fires in the 1950s (north of Route 122 and on the north end of Prescott Peninsula) that killed overstory trees and burned hundreds of acres at high temperatures. The Division's fire policy (Section 5.1.5) and regular improvements in suppression response have limited the impact of fires in the past several decades.

The potential impact of severe fire on water supplies includes the simultaneous death of overstory and understory vegetation and the exposure of mineral soils due to the wholesale consumption of organic materials on the forest floor. The loss of these critical layers exposes the forest soils to erosion by rainfall that reaches mineral soil without the dampening influence of vegetation or organic duff. The loss of organic materials also increases the transport of suspended sediments to watercourses during storm events that challenge the infiltration rate of the soils, especially on steeper slopes (Dissmeyer, 2000). Severe fire that kills riparian vegetation can result in increased stream temperatures and associated changes in stream water quality (Levno and Rothacher, 1969).

Nutrient losses to streams as a result of fire occur when relatively insoluble oxides of cations carried in ashes react with water and carbon dioxide and become more soluble, leading to increased potential for leaching (Debano et al., 1998), and through the acceleration of mineralization and nitrification (the conversion of organic nitrogen to inorganic forms) (Vitousek and Melillo, 1979). Immediately following fire, there is also reduced uptake of these nutrients by plants (because there are fewer living plants), further increasing the likelihood of leaching losses. Nitrate losses to streams and reservoirs can be more pronounced in areas that were approaching nitrogen saturation prior to the fire (Dissmeyer, 2000).

3.4.2.3 Insects and Diseases

Insects and disease-causing organisms are natural components of the forest ecosystem that under ordinary circumstances play a vital role in general biodiversity, decomposition and nutrient cycling, and predator-prey relationships. On the other hand, these organisms are occasionally capable of large-scale infestation and damage, in particular when the specific organism is imported from outside the area and therefore not subject to its normal suite of population-controlling predators. Insects and diseases are a major problem in the Quabbin forest only when their impacts conflict with the Division's objective of creating and maintaining a watershed protection forest. For the most part, this includes only large-scale outbreaks that threaten to alter tree species diversity or forest structure. Chestnut blight, which appeared in central Massachusetts in the first decade of the twentieth century, is an example of such a disease. Before the blight, chestnut was one of the dominant trees in the forest; today, it is essentially a minor shrub.

While native insects and diseases are generally kept in check by their predators, imported or "alien" species can cause significant damage if their natural controls are not introduced at the same time. The potential problems associated with insects and diseases, relative to water supply protection, include the sometimes very rapid defoliation of either a single species or several host species. The foliage of a water supply protection forest controls the erosive force of precipitation, slows decomposition rates by moderating solar radiation, and is the source of evapotranspiration, which moderates soil saturation and helps maintain potential infiltration and storage as a result, all of which work to maintain water quality. Where individual or even small groups of trees are defoliated, these impacts may not be significant, but when a significant percentage of a watershed area is defoliated in a short period of time, the impact on water yield and on the movement of nutrients and sediments can be significant, especially if the understory is not well-developed. For example, large scale defoliation by the fall cankerworm (*Alsophila pometaria (*Harris)) on the Coweeta Basin in North Carolina resulted in a fourfold to fivefold increase in

annual weighted nitrate nitrogen concentrations in otherwise untreated streams, compared to reference streams (Swank, et al., 1981).

3.4.2.4 Climate Change

The relationship between the management of watershed protection forests and climate change is complex. Evidence is overwhelming that the climate is changing and in particular, that mean annual global temperatures are rising. A wide variety of associated changes is predicted, many of which have implications for the long-term management of forests and forested water supplies. It is important to recognize that adaptive changes in forest management in response to predicted changes in the climate may or may not bring about the desired changes in forest structure in time to accommodate the effects of climate change. Forestry has always involved uncertainty in predicting changes and disturbances at the local and landscape scale. Global climate change increases the level of uncertainty managers are required to consider. A broad and conservative response to predicted fluctuations in the global climate is to enhance the forest's inherent natural resilience in order to maintain its ability to adapt quickly to change.

3.4.2.4.1 Weather Extremes

Weather extremes may have begun to rise in magnitude and frequency, although there remains debate about the range of inter-annual variability (Houghton, ed., 1996). More frequent storms with high winds and more intense precipitation, as well as more common occurrence of ice storms and heavy snows have been predicted or have begun to occur. Droughts are more likely as higher temperatures increase evaporation. Higher summer temperatures may favor the geographic expansion of some pathogens or insect pests. Ice storms and heavy snow may weaken individual tree crowns and therefore increase the vulnerability of the tree to pathogens (Broadmeadow, ed., 2001). A reduction in deep winter snow could increase the survival and impact of browsing ungulates. Winter cold injury to trees may be reduced.

3.4.2.4.2 Changes in Species Composition

Changes in species composition may occur in response to higher average temperatures and other changes (Iverson, et al., 1999). Species currently at the northern limit of their range may migrate further north and become locally more common. Species at the southern edge of their limit may become less common. Diseases and insects that affect the current and developing range of species in the Quabbin forest could likewise benefit or lose ground. Alien, invasive plant and insect species may become more of a problem.

3.4.2.4.3 Changes in Seasonal Patterns

Changes in seasonal patterns will have a variety of impacts. The synchrony between hosts and pest development may be altered, with positive and negative results (Broadmeadow (ed.), 2002). While winter cold injury to trees may be lessened, early spring bud break may leave trees more vulnerable to late season frosts. Early spring flushing of forage may enhance the survival of winter-stressed browsing mammals.

3.4.2.4.4 Effects of Rising CO_2

Effects of rising CO_2 levels have already been shown to include increased growth rates due to increased carbon uptake. Leaf area increases that result from increased growth rates also increase water use by plants through increases in transpiration and rainfall interception. Rising CO_2 may also lower the age at which trees become mature and begin producing viable seed (LaDeau and Clark, 2001).

3.4.2.4.5 The Effects of Climate Change on Soil and Water

The effects of climate change on soil and water may include long-term depletion of soil carbon stocks (via increased decomposition rates), although the increased productivity of the forest may counteract this for the foreseeable future, and predicted changes in soil carbon include increases or decreases (Zhou, et al., 2006; Jones, et al., 2005). Predicted increases in foliar densities would depend upon sufficient soil water supply, which is subject to the vagaries of precipitation. While a greater annual average precipitation rate could support greater foliage densities, the distribution pattern of this precipitation will likely have a greater impact than the increase in average volume. If it occurs as intense precipitation that challenges infiltration rates and results in higher peak flows, interspersed with longer dry periods, an increase in annual watershed yield may be more likely than an increase in foliage densities and transpiration rates.

3.4.2.5 Air Pollution and Forested Water Supplies

Air pollution is a chronic disturbance that influences the watershed forest. It also increases the forests value in water supply protection.

- Forests serve as "sinks" for various environmental pollutants, retaining them and slowing their movement into water supplies. A tall, dense, and layered forest serves this function more effectively than a short, sparse forest.

- Environmental pollution has been linked to general forest decline, which increases the susceptibility of those forests to insects, diseases and other impacts.

- Air pollution contributes to nitrogen saturation of forest ecosystems. Nitrogen saturation can cause elevated nitrate, aluminum, and hydrogen levels in streams and losses of cation bases from soils due to soil acidification. These impacts can be compounded by acid precipitation and ozone pollution, and ameliorated by the accumulation of biomass and storage of nutrients in an actively growing forest. Actively growing forests with a diversity of species and sizes may therefore help buffer the impacts of acid precipitation on water supplies.

Concerns about the influence of air pollution focus both on the direct impacts of air pollution on watershed forests and the impacts of resulting ecosystem degradation on water quality. It is extremely difficult to isolate the effects of air pollution from the many other processes and stresses occurring in forest ecosystems (climatic stresses, insects, diseases, fire, ice, wind, etc.). It is also difficult to isolate the impact of one specific pollutant, e.g., ozone or nitric acid, from the composite of impacts affecting a forest. Klein and Perkins (1988) state:

> *I*t is now recognized that no single causal factor is responsible, but that there are a variety of anthropogenic causal factor complexes interacting with natural events and processes that, together, induce stresses in forests that culminate in declines of individual plants and of ecosystems.

3.4.2.5.1 Acid Deposition

Carlton (1990) provides an excellent overview of the impact of acid deposition upon watersheds. In Massachusetts, data indicate that the average pH of precipitation is 4.2, which is six times more acidic than uncontaminated precipitation (Godfrey 1988, as cited in Carlton 1990). In New England, approximately 60-70% of the acid falls as sulfuric acid and 30-40% as nitric acid (Murdoch and Stoddard 1992; Rechcigl and Sparks 1985, as cited in Carlton 1990). Murdoch and Stoddard (1992) note a study in Maine that showed the sulfuric acid component decreasing in recent years, while the nitric acid

component is increasing, leaving the pH of precipitation fairly constant. For example, Stoddard (1991) reported that sulfate deposition had decreased by 1.8% from 1970 to 1984 in the Catskill Mountains of New York. However, the acidity remained the same due to equal increases in the nitric acid component. In Massachusetts, depositions amount to 0.3 to 0.7 pounds of hydrogen ion, 16.2 to 27.5 pounds of sulfate, and 8 to 22 pounds of nitrate per acre per year (Petersen and Smith 1989).

Sulfuric and nitric acids tend to accelerate replacement of aluminum, calcium, magnesium, and other base cations in the soil with hydrogen ions (Hovland et al., 1980, as cited in Carlton 1990). In this way, acid deposition will increase soil acidity and directly impact biological activity, soil fertility, and cation-exchange capacity (Carlton 1990). Acid precipitation can also leach aluminum directly into streams causing potential negative water supply and aquatic and fish impacts (McAvoy 1989). Key factors in determining the susceptibility of watersheds to acid inputs include: the supply of base cations in soils; the percentage of base-rich groundwater flow versus storm flow; the relative importance of snowmelt events; the average storm rainfall intensity, volume, and duration; and the soil depth, texture, pH, and cation exchange capacity (McAvoy 1989; Peters and Murdoch 1985; Veneman 1984). Records at Hubbard Brook, New Hampshire show that while sulfate inputs have declined, base cation inputs from precipitation have also declined (145 micro eq/liter in 1963 to 104 micro eq/liter 1989) causing sensitivity to acidification to actually increase (Driscoll et al., 1989). Decreases in base cations are generally related to a large reduction in suspended particulates since 1970, due to reduction of coal and open burning emissions.

Some researchers have questioned the extent of the impact of acid precipitation. For example, Krug and Frink (1983) feel that most aluminum in streamwater is due to acid soils (caused by natural humic acids) not acid rain. Krug and Frink (1983) and Veneman (1984) note that streamwater can become more acidic as the acid humus layer increases with forest age and because thick humus layers may reduce the amount of water percolating into the subsoil and increase saturated overland flow. Studies in Connecticut and the Berkshires of Massachusetts show that soil acidity increases with forest age (Art and Dethier 1986; Krug and Frink 1983). In Connecticut, litter pH changed from 5.5 to 3.9 from 1927 to 1980 and the mineral soil pH from 5.1 to 4.6 during this period. A study in Norway also concluded that changing land use and consequent vegetational succession was largely responsible for acidification of soils and water (Krug and Frink 1983).

Reuss and Johnson (1986) identified the key difference between natural and anthropogenic acid inputs as the ability of the stronger nitric and sulfuric acids to leach through to stream waters, whereas the weaker natural organic acids will leach from upper to lower soil horizons, acidifying soils but not stream waters. Therefore, a key factor in identifying systems acidified by pollution is whether pH is attributed to organic acids or sulfates and nitrates.

Driscoll et al., (1989) noted that the “acid rain” and “acid soil” argument is largely due to the lack of long-term data on basin soil and water quality. To help resolve this controversy, the authors compared two similar basins, one in New Hampshire (NH) where acid deposition is significant (pH 4.1) and one in British Columbia (BC) where acid deposition is insignificant (pH 5.0). The basins have similar bedrock, glacial history, and soils but differed in vegetation type and precipitation amounts. Both headwater streams were acidic. The key difference was that the BC stream was dominated by weak organic acids, had low aluminum concentrations, and low sulfate loading, while the NH stream was dominated by strong acids (nitric and sulfuric), had high aluminum concentrations, and high sulfate loading.

Two streams in the Quabbin watershed, the West Branch of the Swift River and the East Branch of Fever Brook, received similar analysis to those in NH and BC (Rittmaster and Shanley 1990). The concentrations of sulfate and hydrogen ions in precipitation were significantly higher at Quabbin than at the New Hampshire site. While both Quabbin streams had high aluminum concentrations during high

flow periods, Fever Brook aluminum was in an organic form that is not toxic to fish. Fever Brook also had one half the net export of sulfate of the Swift River, a result of sulfate reduction in the extensive beaver flowage at Fever Brook.

Veneman (1984) rated the ability of the soils of Massachusetts to buffer acid inputs using many of the criteria outlined above. Of the 25 soil types that make up almost all of the DCR lands at Quabbin, only four (all wetland soil types) were classified as "acid precipitation will have no negative impact on water quality," whereas sixteen types are listed as "acid precipitation will have a moderate or significant impact on water quality." Baker (1984) re-measured soil parameters at eight sites at Quabbin that had been measured in 1962. He found that soils had increased in acidity and exchangeable aluminum and were now releasing sulfate, whereas they were adsorbing sulfate in 1962. These changes have reduced the neutralization capacity of the soils.

3.4.2.5.2 Interaction between Air Pollution and Forests

Reuss and Johnson (1986) use the term "canopy leaching" for the process where hydrogen ions replace base cations in the forest canopy. Krug and Frink (1983) report that 90% of the hydrogen ions in acid rain at Hubbard Brook, NH are neutralized in the northern hardwood canopy during the growing season (rain pH of 4.1 changed to 5.0 in throughfall). In studies in the west-central Adirondack Mountain region of New York, Peters and Murdoch (1985) noted that throughfall in deciduous forests was less acid than rain, while throughfall in coniferous forests was more acid than rain.

Local sources of air pollution.

As the forest flora exist in several layers above and below the ground surface, the accumulation/neutralization that occurs at these various layers tells a great deal about how the forest processes incoming acid deposition. Yoshida and Ichikuni (1989) studied the chemical changes to precipitation as it passed through the canopies of three different types of Japanese forests. They reported that from 49-74% of the total incoming acid deposition was neutralized by the forest canopies, with deciduous oak forests neutralizing the least and cedar forests neutralizing the most. Virtually all of the cations and anions studied, with the exception of the hydrogen ion, increased as precipitation fell through the canopy (the authors studied Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, NH_{4+}, H^{+}, Cl^{-}, NO_{3-}, SO_{42-}, and Al). This indicates the process of "canopy leaching" is evident in these forests. The authors note that similar occurrences have been documented in New England by other authors.

Laboratory studies indicate acid precipitation increases leaching of calcium and potassium from vegetative foliage (Smith 1981). In order for the forest canopy to replace the cations and anions lost, similar amounts of these substances must be taken up from the soil. In some cases, acid conditions cause these nutrients to be leached below the root zone where they become unavailable to plants (Klein and Perkins 1988). The net effect of the above processes is to acidify the soils and damage forest ecosystems (Yoshida and Ichikuni 1989).

An increase in the acidity of soil water causes the leaching of aluminum, which is an element of increasing concern to water supply managers. Aluminum also damages fine tree roots and inhibits the uptake of calcium, a nutrient vital to plant growth. This situation leads to further imbalance in nutrients and increases susceptibility to drought stress, decline in growth, and increased mortality (Johnson and

Siccama 1983, as cited in Art and Dethier 1986; Petersen and Smith 1989; Smith 1981). For example, soil acidity is a potential contributor to increased nitrate leaching from forests (Vitousek 1977). Klein and Perkins (1988) report that temperature, moisture, light, nutrients, and soil factors all contribute to susceptibility to disease. This type of pollution may also affect recovery from winter injury.

According to Klein and Perkins (1988), trees undergoing nutrient stresses may be predisposed to decline when natural and pollution-caused stresses are added. Forests in a condition of decline go through a process of "reorganization" during which increased nutrients are leached from the system into tributaries. This increased loss of nutrients may in turn perpetuate the forest decline.

Soil acidity will vary relative to air pollution levels, as well as other factors including soil type and horizon, underlying geology, and successional stage of forest cover (Art and Dethier 1986). In general, the soils of the New England region have a low acid neutralizing capacity or "ANC" (Godfrey 1988, as cited in Carlton 1990). Art and Dethier (1986) studied the relationship of land use and vegetation to the chemistry of soils in the Berkshires. Acidity of the upper-most soil layer was positively correlated to species composition and stand age, with stands less than 140 years averaging pH 4.21 and those over 140 years averaging pH 3.92. Several studies verify an increase in soil acidification with successional sequences following agricultural abandonment (Robertson and Vitousek 1981, Thorne and Hamburg 1985, Krug and Frink 1983, all as cited in Art and Dethier 1986). Acidity varied with land use history, with previously pastured lands having significantly lower pH in the upper horizons than previously cultivated lands. The conclusion is that past land use has a significant impact on species composition and overall soil acidity (Art and Dethier 1986). These studies are useful in considering overall differences in chemical processing in various types and ages of forests and in assessing the potential susceptibility of various forests to impacts of acid deposition.

Soil water pH generally decreases deeper into the soil profile. For example, in a study of eight forest soils in central Massachusetts, mean pH in the A and C horizons were 4.39 and 3.58 respectively; an increase in acidity of eight times. Exchangeable aluminum in the A horizons was nearly four times as high as in the C horizons (Baker 1985, as cited in Carlton 1990).

High levels of ozone cause injury to leaf surfaces of sensitive tree species such as white pine, black cherry, and white ash, especially during summer months. Ozone also reduces photosynthetic rates and the supply of carbohydrates to the roots (Petersen and Smith 1989; Reich and Amundson 1985; Smith 1981). High levels of ground level ozone occur at Quabbin Reservoir, with readings recorded at Quabbin Hill sometimes exceeding other state recording stations including those in Boston.

The combined effects of acid deposition and ozone pollution may be contributing to a measurable decline in Massachusetts forests. A statewide study of the Massachusetts forests identified 24,000 acres that show signs of decline, including yellowing leaves, dead branches, and standing dead trees. This represents a 10% increase in forest decline over twenty years ago (Parker 1988). In addition, the growth rate on one third of the red and white pines studied has dropped 20-50% since the 1960s (Freeman 1987). The overall impact of air pollution predisposes trees to insect and disease outbreaks. For example, research shows that air pollution predisposes pine trees to bark beetle infestations and makes several tree species more susceptible to root rotting fungus (Smith 1981).

In Massachusetts, the decline of red spruce and sugar maple has been examined most closely. Studies of red spruce on Mt. Greylock found that this decline involved a combination of factors, including pathogens, insects, and ice, snow, and wind. However, the decline studied was attributable only in small part to these factors. The high acidity of rain and fog, the high soil acidity, and the low soil nutrient content (including low calcium) at these sites point towards air pollution as a chief cause of the decline of

red spruce. The study of sugar maple decline also concludes that many trees are in a weakened condition, which magnifies the impact of other detrimental factors (Petersen and Smith 1989).

In addition to acid deposition and ozone pollution, current air pollution contains metals, polychlorinated biphenyls (PCBs), alkanes, and various polycyclic hydrocarbons and organic acids (Rechcigl and Sparks 1985, as cited in Carlton 1990). Soil and vegetation surfaces are the major "sinks" for pollutants in terrestrial ecosystems (Smith 1981, as cited in Carlton, 1990). For example, the leaves and twigs of an average sugar maple tree 12 inches in diameter will remove the following elements from the air in one growing season: 60 mg of cadmium, 140 mg of chromium, 5800 mg of lead, and 820 mg of nickel (Smith 1981). Klein and Perkins (1988) reported that the accumulation of metals affects nitrogen transformations in hardwood forests.

Forest soils serve as sinks for lead, manganese, zinc, cadmium, nickel, vanadium, copper, and chromium; tree trunks also serve as sinks for large amounts of trace metals including nickel, lead, chromium, cadmium, and manganese (Smith 1981; Driscoll et al., 1989). The U.S. Environmental Protection Agency designed a 40-acre "model forest" containing several hardwood species and white pine (Smith 1981, as cited in Carlton 1990). The model predicts that, within five years of planting, this hypothetical forest and its soils would annually remove the following pollutants:

- 96,000.00 tons/year of ozone
- 748.00 tons/year of sulfur dioxide
- 2.20 tons/year of carbon monoxide
- 0.38 tons/year of nitrogen oxides
- 0.17 tons/year of peroxyacetylnitrate

The net effect of air pollution on a forest ecosystem is a combination of decreased photosynthesis, decreased growth, increased respiration, reduced biomass, and possible reductions in reproduction. These impacts produce a range of symptoms that together are termed "forest decline." The severity of the decline depends on the amount of pollutants, and the species and site conditions involved. An additional impact of air pollution is alteration of forest ecosystem composition and structure, through selectivity of impact. More severe air pollution, and air pollution on naturally stressed sites, serves to simplify the overall make up of the ecosystem and make it less diverse and less stable (Klein and Perkins 1988; Smith 1981). Smith (1981) defines three classes of air pollution impacts:

- *Class I*: low dosage, where the ecosystem serves as a sink for pollutants.
- *Class II*: intermediate dosage causing nutrient stress, reduced photosynthesis and reproductive rate and increased predisposition to insects and diseases.
- *Class III*: high dosage where mortality is widespread and gross simplification of the ecosystem alters hydrology, nutrient cycling, erosion, microclimates, and overall ecosystem stability.

Klein and Perkins (1988) reviewed more than 400 studies relating to forest decline and concluded:

> There are interactions between primary causal complexes and their direct effects and secondary causes and consequences of forest decline discussed here, so that the web of interactions becomes formidable. Nevertheless, a start must be made on these analyses, not only to understand forest decline holistically, but also because of the pressing need to develop concepts and strategies to ameliorate or reverse the imminent collapse of forested ecosystems. Recognizing that species sensitivities to causal factor complexes vary greatly, inevitable simplification of ecosystems will drastically affect their ultimate stability.

3.4.2.5.3 Nitrogen Saturation

3.4.2.5.3.1 Overview

The potential problem of nitrogen saturation, defined as the declining ability of an ecosystem to retain added nitrogen, was only identified in 1981 (Aber 1992). Researchers are concerned that acid deposition may also be adding significant amounts of nitrogen, originating chiefly from nitrogen oxides in air pollution. The effects of nitrogen saturation include elevated nitrate, aluminum and hydrogen ion concentrations in stream water (Van Miegroet and Johnson 1993). Monitoring of nitrates is required for drinking water (standard=10 ppm) because of health effects upon infants and potential formation of carcinogenic byproducts (Skeffington and Wilson 1988). Nitrates can also cause algal blooms in lakes and reservoirs. Excess nitrogen deposition may also affect forest composition and productivity (Aber 1992).

Bormann and Likens (1979b) report a doubling in nitrate concentration in precipitation since 1955. Schindler (1988) reports that deposition of nitrogen oxides has increased much more rapidly than sulfates in recent decades. Ollinger et al., (1994) report that there is a more than twofold increase of wet nitrate deposition from east to west between eastern Maine and western New York State. The authors mapped broad-scale wet and dry nitrogen deposition across the Northeast, with the Catskill region in the highest category (10.34-12.66 kg N/ha/yr) and the Quabbin region in the lower (7.99-9.16 kg N/ha/yr) category.

3.4.2.5.3.2 Processes Involved

The processes related to nitrogen saturation are more complex than those related to precipitation inputs of sulfates, mainly because nitrogen can be both an acid and plant nutrient component and due to the complex interactions between soils and plants and the various compounds of nitrogen. In the ammonium form, nitrogen is a nutrient for the plant/soil biota complex. In the nitrate form, nitrogen can be a nutrient for biota but can also be a very mobile and dominant anion involved in base cation depletion and mobilization of aluminum through the soil and into stream water.

A key reaction in this process is nitrification, the conversion of ammonium to nitrate. Others are denitrification (in which atmospheric nitrogen is released from nitrates) and nitrogen mineralization (the process by which ammonium is formed from organic nitrogen in soils). Mineralization is an important process, as the storehouse of nitrogen in soils far exceeds that in the plant system (75-97.5% of nitrogen is in inorganic form in soils) but the nitrogen can be more mobile in the plant system. As long as the soil system delivers an amount of nitrogen less than or equal to the capacity of the plant system, nitrogen is held within the system. Thus, nitrogen saturation requires both the soil and plant systems to be saturated.

The interaction of these three processes – nitrification, denitrification, and nitrogen mineralization – is dependent upon various bacteria, pH levels, season and climate, as well as variations in plant/soil composition. An added complication is the process of nitrogen fixing, by which plants transform nitrogen gas (the most prevalent component of the atmosphere) to nitrogen in a usable form in the soil/biota system. The relative importance of nitrogen fixation is dependent on the composition of nitrogen-fixing plants in the system. Bormann and Likens (1979b) estimate that 70% of the nitrogen store at Hubbard Brook, NH is derived from fixation and the remainder from deposition. In general, predictions of the timing of the onset of nitrogen saturation are limited by the lack of understanding of soil properties and the complex processes at work there (Schofield et al., 1985; Agren and Bosatta 1988; Nadelhoffer et al., 1984; Aber 1992,1993).

Disturbance of the plant/soil system by natural or anthropogenic events tends to increase mineralization of nitrogen and consequent nitrification in the system. Vitousek et al., (1979) analyzed processes that keep nitrate leaching in balance. These include the accumulation of ammonium in soil solution on cation exchange sites in the soil, and lack of soil water for nitrate leaching. A delay in nitrate movement after disturbance is critical as this allows vegetation to develop and take up much of the available nitrate before it can leach into stream waters.

Van Miegroet and Johnson (1993) summarize the complexity of the nitrogen saturation process:

> This soil condition is the integrated result of vegetation type, age and vigor, past N accumulation history, climatic conditions, and current and past N input regime and soil characteristics.

Aber et al., (1989) have developed equations based on field work that can help model the nitrogen cycle using soil litter analysis.

3.4.2.5.3.3 Symptoms and Site Susceptibility

Aber (1992) describes the characteristics – including annual stream water nitrate trends – of nitrogen-limited, nitrogen-transition, and nitrogen-saturated systems. In general, nitrogen-limited systems have low nitrate loss during snowmelt, high carbon to nitrogen ratios in soil litter, and high soil dissolved organic carbon concentrations. Nitrogen-saturated systems exhibit the reverse conditions for these three criteria. The identification of elevated nitrates in storm events, especially during snowmelt, may be a first indication that system inputs are exceeding capacity, at least temporarily. For example, researchers at the New York City water supply watersheds in the Catskills are concerned about peaks of nitrates in the spring (up to 128 micro eq/l) combined with elevated summer levels (Murdoch and Stoddard 1992). Rittmaster and Shanley (1990), in a study of two tributaries at the Quabbin, reported that nitrate concentrations were generally low, but nitrate peaks of 20 and >35 micro eq/l were reported in the two streams during the snowmelt period. The authors attributed these peaks to short soil contact time during storms. There are no other records of nitrate peaks at Quabbin, but limited storm sampling has been done.

Brown et al., (1988) recommend consideration of vegetation type and age, site history, carbon: nitrogen ratios in soil organic matter, external inputs, and nitrogen turnover rates to thoroughly evaluate the condition of a system with regard to nitrogen saturation. The authors note that because natural plant communities change, nitrogen saturation is a "moving target." Van Miegroet and Johnson (1993) reported that forests with small soil nitrogen pools, due to either limited accumulation history or frequent disturbance such as fire, generally have low nitrification potential and insignificant nitrate leaching, irrespective of age or vigor of the forest. Sites that have high soil nitrogen content coupled with a low carbon to nitrogen ratio have a high nitrification potential, and under these conditions the annual leaching of nitrates is strongly dependent on atmospheric inputs, forest age and tree nitrogen uptake rates.

3.4.2.5.3.4 Impacts of Forest Succession and Disturbance

Stand age is an important factor in determining nitrogen uptake and annual nitrogen accumulation rates in tree biomass. A declining trend in nitrogen immobilization as a stand matures may explain why nitrate leaching losses are typically larger in mature versus vigorously growing forests. Long periods without disturbance may allow high nitrogen accumulation and low carbon to nitrogen ratios and increased nitrification potentials (Van Miegroet and Johnson 1993). Hemond and Eshleman (1984) note that both higher plant uptake and microbial immobilization contribute to limiting nitrate losses from Temperate Zone mid-successional forests.

Murdoch and Stoddard (1992) state:

> In watersheds where forests are accumulating biomass, biological demand for nitrogen is often sufficient to retain virtually all atmospherically deposited and mineralized nitrogen during the growing season and reduces net nitrate release to stream water.

In their analysis of elevated summer nitrate levels in Catskill Mountain streams, Murdoch and Stoddard hypothesized that the older forests in the Catskill Preserve may have a low demand for nitrogen and may therefore be unable to retain all of the atmospheric nitrogen entering the watersheds. In a study of N-cycling within the long-undisturbed Biscuit Brook watershed in the Catskills, annual rates of N leaching from this older forest were more influenced by temperature-related differences in N processing (nitrification, mineralization) than by differences in N deposition rates, leading to speculation that climate warming could accelerate the pace at which an area approaches N saturation (Murdoch et al., 1998).

Aber et al., (1991) note that changes in species composition may affect the ability of a forest to absorb nitrogen. For example, due to longer needle retention, pine takes up less nitrogen than oak or maple. The authors also modeled the timing of nitrogen saturation of a hypothetical forest under different scenarios. For example, forest harvesting (removal of nitrogen) slowed the onset of saturation; ozone pollution reduced net primary productivity and moved the onset of saturation up from 300 years in the future (without ozone pollution) to 50 years into the future (with ozone pollution); and alteration of forest species from low nitrogen-demanding to high nitrogen-demanding species delayed the onset of saturation. This modeling exercise did not examine the impact of forest succession. In the Catskill Mountains, differences in N saturation and retention among forested watersheds seems to be related to differences in species composition and forest history, which in turn relate to forest succession (Lovett et al., 2000).

3.5 Resistance and Resilience in the Watershed Forest and the Role of Management

3.5.1 Forest Filtration: Redundancy and Diversity

A frequently applied principle in civil engineering is to design *redundancy* into systems built to serve and protect public health by duplicating critical components so that failure of primary systems does not present insurmountable risks. The drinking water supply biofilter provided by the forest is naturally redundant in the protection that it provides. This redundancy includes multiple opportunities for mitigating the kinetic energy of rainfall, the source of erosion, through layers of vegetation in the overstory, midstory, and understory, and the accumulated organic debris on the forest floor. In a fully functioning forest, redundancy includes the regular production of seed by mature trees, enabling their rapid regeneration when needed. Chemical filtration redundancy in the forest includes denitrification of inorganic nitrogen to nitrogen gas in the canopy as well as at the forest floor coupled with microbial remediation of pollutants within the forest soil. Roots within this filter provide reinforcement that adds to forest soil stability while they are alive, and increase soil porosity when they die and decay, therefore increasing the generally high infiltration rates of forest soils. In spite of its redundancy, the forest is unlike an engineered water filtration plant in that it is a living, dynamic system whose components change constantly, in response to growth and competition, mortality, and a wide range of disturbances that affect it on scales ranging from a fraction of an acre to the majority of a watershed. Therefore, building redundancy requires consideration not just of the structure of the static biofilter that exists at a given point in time, but also of working with natural processes to build long-term *resistance* and *resilience* in these natural filtration systems.

Ecological principles of diversity relate to the engineering concept of redundancy in the context of a biofilter. Both lead to stability in the system, to its ability to continue to function in spite of disturbance,

to resist changes in its desired functions and/or to recover those functions quickly following disturbance. A forest that is low in species diversity is more susceptible to mortality than a mixed species forest when species-specific pests arrive (e.g., gypsy moth in an oak-dominated forest). A forest that is predominantly composed of tall trees may be more susceptible to wind damage than a forest with mixed height classes. Beyond these self-evident sources of system stability through diversity, regions within these watershed forests are further categorized by their relative influence on water resources. Riparian forests are expected to consistently provide water quality control through high soil infiltration rates and rapid nutrient uptake. Upland forests are expected to yield water at consistent rates while preventing the loss of sediments or nutrients to the riparian forests or directly to streams through subsurface flow. To avoid sudden changes in these functions, these forests are expected to be able to resist damage and/or to regenerate quickly when damage occurs.

The most catastrophic damage that typically occurs in the New England forest has historically been produced by low-frequency, very high intensity hurricanes. The amplitude of the changes brought about by these disturbances is a function both of the intensity of the storm and the susceptibility of the forest. The hurricane of 1938 did vast damage, but the New England forest at that time was still rebuilding following farm abandonment that began in the mid to late 1800s and large scale cutting of old field pine at the turn of the century. Were the same storm to strike today, it would impact a more vulnerable forest, one that has grown consistently older and taller across the landscape except where management or smaller scale disturbances have rejuvenated it since 1938. Among the objectives for active management of watershed forests is to reduce the amplitude of unavoidable natural disturbances, through deliberate rejuvenation of a small portion of the forest each year. This general concept is simplified and depicted graphically in **Figure 12**, showing the amount of forest that was or might have been disturbed with and without management, by the hurricanes of 1635, 1788, 1815, and 1938.

3.5.2 Nutrient Dynamics

Understanding the influence of the forest on water resources requires an understanding of nutrient dynamics within these ecosystems. U.S.D.A. Forest Service researchers have detailed the hydrologic and nutrient dynamics in experimentally manipulated northern hardwood forests at Hubbard Brook in NH (Bormann and Likens, 1979). They describe the stages that a forest passes through following disturbance to the overstory without destruction of the biological, hydrological, and nutrient properties of the soils.

1. A relatively brief *reorganization phase*, during which the ecosystem loses total biomass despite accumulation of living biomass.

2. A much longer *aggradation phase*, during which the system continuously assimilates nutrients and accumulates biomass.

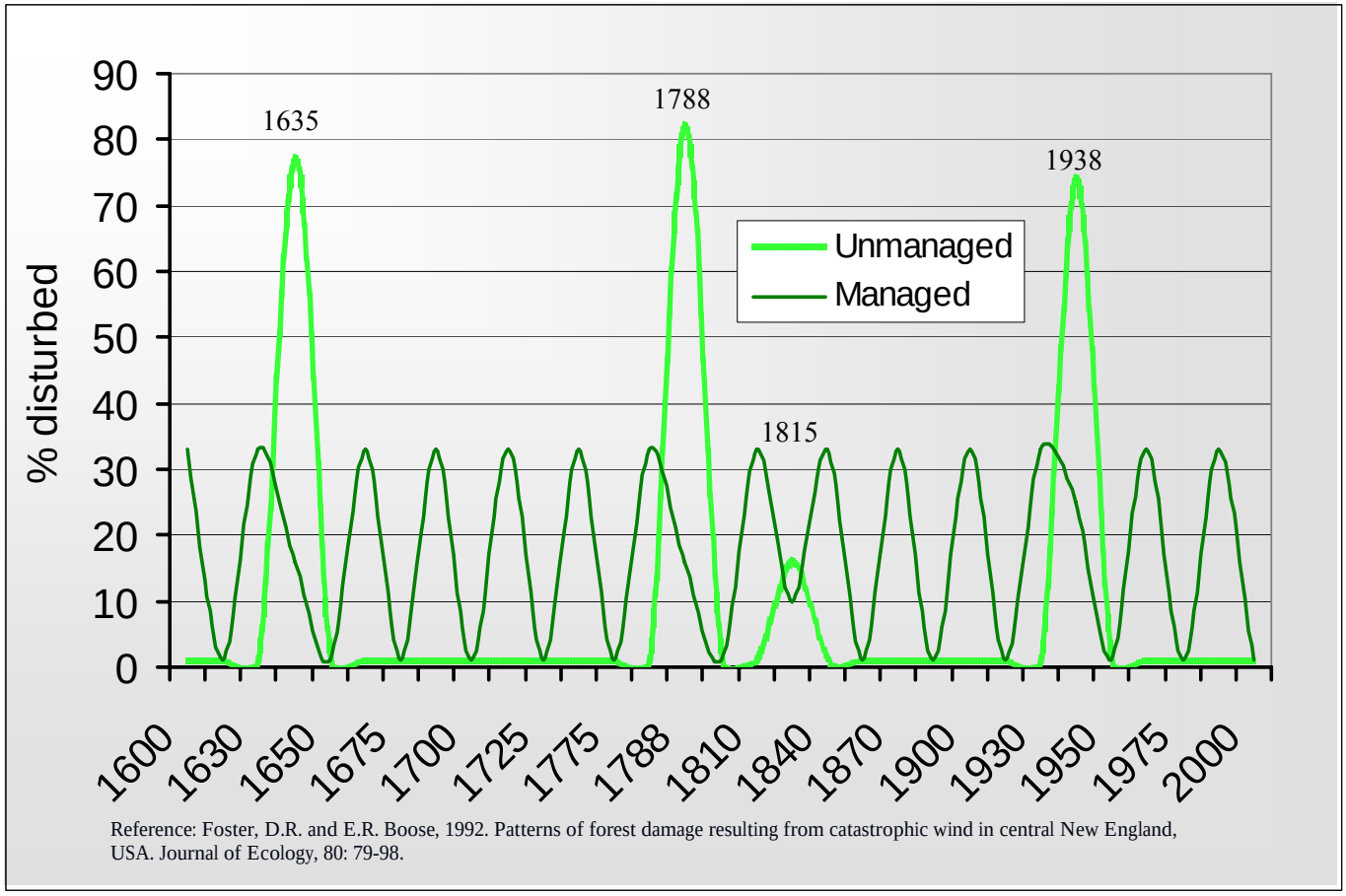
3. A variable length *transition phase* that occurs as the forest reaches a point where biomass accumulation slows and age-related mortality increases.

4. A *steady state*, at which point biomass losses from mortality are balanced by biomass accumulation that results from regeneration.

The progression of the forest along this path assumes that no additional large-scale catastrophic disturbance intervenes. The nutrient dynamics that accompany these phases also vary through time. The greatest regulation of nutrient export occurs during the aggradation phase, while losses are associated with both the reorganization and transition phases, and a relatively consistent level of control that is somewhat lower than during the aggradation phase is associated with the steady-state phase. Control over nutrient export following disturbance is provided by incorporating nutrients in accumulating biomass. If

it were possible to maintain an entire watershed forest in an aggrading condition, nutrient control could be held at an optimum level. But the forest is a dynamic system, moving along these phases steadily unless disturbances interrupt this progression.

Figure 12: Amplitude of Wind Disturbance in Unmanaged vs. Managed Forests



3.5.3 Forest Structure and Water Yield

Studies throughout the eastern United States have documented changes associated with removing overstory forest from a forested watershed. At Coweeta Hydrological Laboratory, in Franklin, North Carolina, increases in streamflow correlated well to both the percentage of basal area removed and the solar radiation load, which relates strongly to aspect (Douglas and Swank, 1975). Removal of vegetation temporarily reduces evapotranspiration, so that the largest increases in streamflow on cut versus uncut watersheds occur during the growing season. Studies at the Fernow Experimental Forest in West Virginia documented a strong correlation between soil moisture in the upper two feet of forest soils and streamflow, so that growing season soil moisture deficits in fully forested stands are reduced with cutting, resulting in increased discharge (Kochenderfer and Aubertin, 1975). Cutting alone will not produce this increase in discharge, but will cause it when subsequent precipitation events eliminate soil moisture deficits (Hornbeck and Federer, 1975). For partial cuttings that retain residual forest, the exposure of edge trees adjacent to openings increases their rate of growth and transpiration, resulting in a reduction of the yield that would be associated with full clearcuts (Hornbeck et al., 1975). Partial cutting may also

reduce snowmelt maximum discharge; the more rapid melting of openings desynchronizes the overall watershed melt (Hornbeck et al., 1975).

Forest hydrology research from 1900 to 1970 focused on water yield and sedimentation concerns. It was demonstrated repeatedly that producing measurable increases in yield required reducing watershed forest canopy by at least 20-30%, and furthermore that sediment loss following these canopy changes was almost entirely the result of poorly designed or constructed roads (Ice and Stednick, 2004). Many of these experiments involved paired watershed comparisons of undisturbed forest to forests that were either completely or partially clearcut (Stednick, 2000), but few were designed to test systematically dispersed partial harvesting or small group selection cutting.

The Leading Ridge Watershed Research Unit in Pennsylvania demonstrated that these are important matters by testing the yield results of cutting the upper versus the lower half of a watershed. Hubbard Brook researchers tested strip cuts, not a common practice in the Northeast and generally limited to plantation management. Harr and Frediksen (1988) tested "patch cut" partial harvesting in the watersheds that supply Portland, Oregon, but the smallest patch studied was 7.9 acres in size, an opening size that would be considered to be an even-aged clearcut in the Northeast U.S. A water yield experiment in a second-order watershed of Quabbin Reservoir tested small group patch cuts, but also cut or killed all trees within 100 feet of the tributary to test the water yield effects of greatly reducing riparian zone evapotranspiration (Mader et al., 1972). Cutting on Catchment 3 at Fernow included 2 "intensive selection cuts" removing 13% and 8% of the stocking, followed by a cutting of 0.5 acre patch cuts that removed an additional 6%, and finally a clearcut of the remaining stocking (Hornbeck et al., 1993). In general, once basal area removal exceeds 25% of the watershed total, the change in yield during the first year following removal is roughly proportional to the percent of the total basal area that was removed.

3.5.4 The Importance of Pattern

The importance of the configuration of partial cuts in predicting water yield was clarified in paired watershed experiments by comparing partial cuts ranging from 24% to 33% of the catchment basal area, but distributed differently, at Hubbard Brook, Fernow, and Leading Ridge experimental forests. The greatest yield of these partial cuts came from cutting 24% of Catchment 2 at Leading Ridge, which produced nearly twice the yield increase produced by cutting about 33% of the stocking on Catchment 2 at Fernow and Catchment 4 at Hubbard Brook. The basal area reduction at Leading Ridge was produced by clearcutting the lowest portion of the catchment, while cutting at Hubbard Brook was in alternating strips and cutting at Fernow was a diameter-limit removal of scattered individual trees (Hornbeck et al., 1993). Clearly, pattern, placement, and distribution of cutting have an effect on water yield, which in turn has implications for water quality.

Vitousek (1985) addressed pattern in determining nutrient cycling within patches, suggesting that there is a critical patch size below which nutrients and water made available by disturbance are likely incorporated in the intact forest at the edge of the opening (and above which nutrients and water may be more mobile). He further speculates on the watershed-level effects of patch disturbance:

> *A final question is, to what extent can vegetation patches within a watershed interact to influence ecosystem-level nutrient dynamics? Nutrients leaching through the soil from disturbed patches toward streams or groundwater could be taken up by adjacent aggrading patches or by the riparian vegetation near streams if patch sizes are small and if percolating water is not too deep. In such a case, the watershed as a whole could retain nutrients more effectively than any individual patch, and natural vegetation made up of a mosaic of patches could be significantly more retentive than vegetation managed*

in large patches. Some experimental forest management schemes based on this possibility have been implemented (Hornbeck et al., 1975) or contemplated (Jordan, 1982). If these practices are useful and widely applicable, the management of patch dynamics would become an important way to manage the nutrient capital of terrestrial ecosystems.

Satterlund and Adams (1992) further discuss the importance of pattern in controlling water yield, which in turn controls the associated loss of nutrients and sediments. While there are issues of practicality in implementation, disturbing (harvesting) 25% of a watershed's forest cover through widely scattered small openings will yield less water and associated nutrients than concentrating this disturbance in a single block. The difference is in the control over yield that is exerted by the intact forest at the edge of the openings. The greater the ratio of edge length to opening size, the greater the control over yield will be. Therefore, managing the dynamic changes in the watershed forest's stage of development, by deliberately rejuvenating small, well-dispersed patches, could maintain an aggrading, nutrient-controlling condition across the watershed without exposing adjacent tributaries to the nutrient loss spikes associated with disturbances that affect large, homogenously vulnerable patches.

The importance of forest pattern in developing resilience in the biofilter is also evident in peak flows associated with snowmelt. Snowmelt is often the strongest peak flow of the water year. Verry (1986), discussing the differences in long wave radiation energy added to the snow pack by mature versus young stands points out that "because there is a five-day difference between peak snowmelt flows in clearcut and older stands, harvesting will desynchronize snowmelt within a forested area and actually reduce flood peaks by 30 percent when a mosaic of young and older stands exist in the same area." Satterlund and Adams (1992) echo this, stating that "All in all, it appears that management systems that are designed to increase the natural heterogeneity of a watershed will flatten and broaden the snowmelt hydrograph. Cutting systems that increase homogeneity will sharpen it." Stronger peak flows carry the possibility of stronger losses of sediments and nutrients to tributaries and receiving reservoirs.

3.5.5 Age Structure and Resiliency

Murdoch and Stoddard (1992), in describing the potential sources of nitrogen they observed being flushed from streams in the Catskills during storms and spring snowmelt, offered the following as one possible explanation:

Neither the major source of nitrate during storm flow and snowmelt, nor the causes of long-term increases in nitrate concentrations in Catskill streams, can be identified with certainty. In all likelihood, both atmospheric deposition and natural processes contribute to the increasing nitrate concentrations in Catskill streams. Changes in nitrogen deposition rates alone cannot account for the nitrate trends in streams observed here, as mentioned earlier. However, episodes of high nitrate concentrations will result if the terrestrial ecosystem fails to retain atmospherically deposited nitrogen. The headwater forests of the Catskill Mountain region have not been logged since 1870, when they were incorporated into a state preserve, and major forest fires have not been reported since the 1840s. In general, young, rapidly growing forests will retain more nitrogen than forests that are mature or growing slowly. The Catskill forests may therefore have a low demand for nitrogen because they are at or near maturation, and can no longer retain all of the atmospheric nitrogen entering the watersheds.

The concept of nutrient "leakiness" of very old forests, which proposed that gradual declines in net productivity as senescence begins to balance growth might explain nutrient losses from these forests

(Vitousek and Reiners, 1975), has been further tested in unmanaged forests in Chile. In old-growth temperate forests in southern Chile, it is clear that nutrient uptake potential is less than in an aggrading, younger forest, but even in very old forests in this region, nutrients are still very tightly cycled between litter and living biomass, and only very minor amounts are lost to water courses (Hedin et al., 1995).

The difference between these forests and those of the Catskills, where old, undisturbed forests are losing nitrogen to the streams, may be primarily the difference in atmospheric inputs. The Catskills are among the regions on the receiving end of atmospheric nitrogen that accumulates from the burning of coal to produce power in the Midwest. Prevailing westerlies carry this nitrogen source to the Catskills, and the relatively low buffering potential results in losses. The old forests in Chile may be at similarly low uptake capacities, but do not receive the atmospheric inputs, and therefore do not flush nitrogen during peak flows. Nonetheless, these older forests are apparently more vulnerable when excess nitrogen does arrive, and the general conclusion of Vitousek and Reiners (1975), that "intermediate-aged successional ecosystems will have lower nutrient losses than either very young or very old (mature) ecosystems" may hold up well in areas receiving increased atmospheric nitrogen inputs.

3.5.6 The Effects of Management on Resistance and Resilience: A Working Hypothesis

The watershed protection forest, as described in Section 3.5.5, has built-in processes that, with or without active management, collectively resists change and rapidly works to recover equilibrium following a natural or deliberate disturbance. Experience has demonstrated, however, that there are opportunities to enhance these natural processes through active management. Past land management practices have had a lasting impact on Quabbin's watershed forest in the following ways:

- For many decades, the loss of both natural predators and hunting by humans left deer populations as the dominating influence over the regeneration of the forest following disturbance. Deliberate management of this population, beginning in 1991, has restored the regeneration process, although a growing, unchecked moose population has begun to challenge it again.

- The artificial planting of several thousand acres of agricultural fields to white and red pine homogenized the age and species composition of these new forest stands, many of which were planted on sites on which they were eventually susceptible to root rot and wind throw. Removing these plantations in stages has resulted in new age classes of site-suited natural regeneration that is diverse in species composition, a generally more stable forest structure.

- With the regeneration process restored, management has moved from improvement thinnings to regeneration harvesting designed to create a mosaic of age classes across the forest that mimics the annual 0.5 to 2.0% natural disturbance cycle but in a more regulated pattern. While infrequent catastrophic disturbances will still arrive on the watershed, the forest that these will affect will include well-distributed patches of forest that are resistant to these disturbances, due to enhanced vigor or to age, size, or species diversification, or to a combination of these elements.

Other evidence from the science of forested watershed management offers additional and compelling reasons to consider active manipulation:

- Snowmelt, which generates some of the highest peak flows in a water year, is synchronized to the extent that a subwatershed is homogenized in species or size class,; it all occurs within a single relatively narrow time period, maximizing the peak event. On the other hand, a subwatershed of mixed species composition and a variety of age classes tends toward desynchronization, because patches of snow gathered within differing stands will melt at different rates, resulting in a longer

length, but lower amplitude peak flow. This in turn limits bankfull stream conditions and the associated erosion of accumulated sediments and organic materials.

- Experimentation with strip and small patch cutting has verified the ability of retained patches, if the balance is carefully designed and maintained, to capture and utilize water and/or nutrients that have been mobilized by the cutting of adjacent stands. Within some site-specific limits, the diversification of size classes within the forest can be accomplished without exceeding the ability of the residual, undisturbed, adjacent forests to control losses of water, nutrients, and sediments. Once this diversification has been accomplished, the standing forest structure should be more capable of resisting and rapidly recovering from large scale, outside disturbances.

- Research in nutrient cycling indicates that the maintenance of a steady component of aggrading, middle-aged stands within a watershed forest that includes all age classes should optimize the buffering of further nutrient inputs, for instance when these arrive via atmospheric deposition. Maintaining this forest structure requires steady recruitment of younger forest to replace middle-aged stands that have matured.

Active management carries risks that can reduce or eliminate the potential gains associated with deliberate manipulation. Current research on these risks indicates that by following a few clear rules, these risks can be controlled or eliminated:

- Researchers have shown that a minimum of 20-30% of the stocking of a forest must be cut within a short time (1-3 years) to increase water yield. Conversely, to minimize yield increases and the loss of nutrients or sediments that may accompany yield increases, managers need to limit harvesting to not more than about 25% of the stocking on a forested watershed in any given 5-10 year period.. Using GIS and GPS technologies, it has become possible to maintain these standards fairly efficiently.

- Separating the roads and staging areas from water resources is among the basic rules to protect those resources from negative impacts due to logging. Roads should be designed to minimize stream crossings and stormwater drainage structures need to be properly designed and maintained. Staging areas should be kept far enough away from water resources to be hydrologically remote.

The working strategies for actively managing the Quabbin watershed forest to take advantage of some of these principles are:

- To maintain the ability of the forest to regenerate itself.

- For the next decade, to annually regenerate approximately 1% of the actively managed forest, using small group selections or patch harvesting to maintain multi-age class structure and diverse species composition.

- To strictly adhere to Conservation Management Practices that have been customized for drinking water supply protection.

- To limit harvesting to no more than 25% of the stocking of any given subwatershed during any given 10 year period.

3.5.7 Wildlife Effects

The wildlife effects of greatest concern in the development of resistance and resilience in the watershed protection forest are those that limit the establishment and development of plants, particularly trees. The stability and long-term functioning of the biological filtration provided by the watershed forest is dependent upon its ability to grow and reproduce perpetually, following a wide range of disturbances.

While low populations of browsing ungulates (deer, moose) can be accommodated within the watershed protection forest while maintaining sufficient forest structure, there are limits to this accommodation. Deer populations in excess of 15-20 per square mile begin to limit both the species composition and the ability to meet minimum densities of tree regeneration following disturbances to the overstory. Moose weigh nearly 10 times as much as white-tailed deer and consume 50-60 pounds of vegetation per day. In addition, they are capable of feeding on tall saplings, by breaking their stems to bring the canopy within reach or by simply walking over them to bend them to the ground. In order to escape moose browsing, trees need to be much larger than the 4-5 feet tall that is considered to be beyond regular deer browsing reach. In extreme cases of heavy browsing, tree regeneration is nearly absent, so that the values for water quality protection that are associated with maturing trees (Section 3.3) are also absent.

4 Watershed Management Goals

4.1 Drinking Water Protection Goals

4.1.1 Water Quality Goals

The enabling legislation for the Division of Water Supply Protection directs the agency "… *to assure the availability of pure water for future generations."*

Water quality in the Quabbin Reservoir depends on many watershed features, including natural characteristics, land use, and hydrology. A major tenet of watershed management is protection through ownership of watershed lands. Owning and managing watershed forest lands is recognized as the most direct and proven method of protecting long-term water quality.

The Division of Water Supply Protection continually assesses the quality of the water, and develops management strategies that assure the availability of clean water. DWSP has defined primary and secondary water quality goals for the system.

Primary Goals for Water Quality

- PREVENT WATERBORNE DISEASE.
- MEET THE SOURCE WATER COLIFORM CRITERION.
- MAINTAIN HIGH QUALITY SOURCE WATER.

Secondary Goals for Water Quality

- REDUCE/CONTROL NUTRIENT INPUTS TO THE RESERVOIRS.
- REDUCE RISK OF A CHEMICAL OR HAZARDOUS MATERIAL SPILL.
- CONTROL GENERAL POLLUTANT TRANSPORT INTO THE RESERVOIR.

These goals are used to make and evaluate all management decisions. The Division's Environmental Quality Section routinely collects samples from stations on tributary streams and from reservoir stations at Quabbin. The water quality data are reviewed as part of DCR's Watershed Management Program decision making process. Additionally, MWRA has a detailed water quality sampling program beginning at the Cosgrove Intake and throughout the water transmission and distribution systems. These data are used with the Environmental Quality Section's data to continually monitor the reservoir and watershed systems.

The maintenance of DWSP controlled land to provide the best watershed cover to protect water quality is the overall goal of the Land Management Plan. The main water quality concerns in land management are:

- **Limit pathogen introduction and transport to the reservoir and intakes**. This goal will be met primarily through continuation of the *Gull Harassment Program* and *The Aquatic Mammal Pathogen Control Program* as well as by maintaining a vigorous forest cover throughout the watershed (see section 5.4.4).

- **Limit turbidity and sediment transport.** Although the size of the Quabbin Reservoir and the location of the intakes prevent localized sediment transport from affecting drinking water quality during normal events, making sure the watershed can control sediment transport during and following major disturbances is a guiding goal of the Land Management Plan. In addition to addressing major events, control methods focus on preventing sediment transport from the road system and during active forest management activities.

- **Limit nutrient transport to the reservoir.** Although Quabbin Reservoir on the whole is oligotrophic (low in dissolved nutrients and rich in dissolved oxygen), there have been nutrient-related algae blooms in the past that affected taste and odor. Nutrient transport to the reservoir will be limited through protection of riparian zones and by maintaining vigorous forest growth throughout the watershed.

- **Maintain the low Total Organic Carbon (TOC) level in the reservoir.** One of the parameters that exemplify the high quality of water in the Quabbin Reservoir is its low TOC levels. While all the links between land management and TOC are not clear, the high percentage of forest cover appears to be associated with low TOC levels. Further research will gradually quantify the sources of TOC and its watershed-scale control.

4.1.2 Water Yield Goal

- WORK TO MAINTAIN CURRENT WATER YIELDS TO THE QUABBIN RESERVOIR

In the past, insufficient supply was a concern for the system, resulting in management efforts to increase yield, as well as proposals to divert waters from the Connecticut or Millers Rivers to increase the Quabbin supply. Significant effort was devoted to developing land management strategies that would increase water yield, including converting pine plantations back to fields (because grass cover uses significantly less water than maturing conifer cover, resulting in greater yield). Concurrently, the MWRA has devoted considerable efforts to managing demand; as a result, the overall system demand has significantly decreased (see Figure 2 above). Water demand in 2004 decreased to the level of the system demand in the 1920s, and demand is predicted to remain well below safe yield into the foreseeable future. Unless the system is greatly expanded, current yields are well above demand and there are currently no plans for yield enhancement under consideration.

4.2 Land Protection Goals

- CONTINUE WORKING TO LIMIT LAND USES ON THE WATERSHED TO THOSE THAT DO NOT THREATEN WATER QUALITY.

- PROVIDE CONTROL OVER NON-FOREST LAND USES, THE EFFECTS OF NATURAL EVENTS, AND HUMAN ACTIVITIES THAT THREATEN WATER OR OTHER NATURAL RESOURCES.

Control over harmful activities on the Quabbin Reservoir watershed is best achieved when the Commonwealth has actual ownership or other direct control over allowable activities on the land. DWSP has an active land acquisition program geared towards acquiring ownership or other rights on key parcels on the watershed - primarily those near principal tributaries and wetlands. Once acquired, these lands can then be managed to establish and maintain optimal cover types that provide for the long-term protection of water quality.

The location, marking, and maintenance of the boundaries of DWSP watershed lands are important land protection activities, since clear boundaries allow for better control over illegal activities that could threaten watershed integrity. Effective resolution of boundary encroachments is an integral part of boundary maintenance.

The control of potentially harmful activities on watershed lands requires a human presence on those lands, both to identify and locate those activities, and to provide effective enforcement of rules and regulations. This presence is provided by DWSP personnel, and is a principal responsibility of the DWSP Watershed Rangers. This presence allows for the timely discovery and resolution of potentially harmful human activities (e.g., illegal dumping) and natural events (e.g., fires) on the watershed.

Effective monitoring and control also depends on a good road system that allows quick access to all parts of the watershed lands. However, since gravel roads can also be a source of sediments for streams and water bodies, watershed road maintenance strives to disconnect roads from water sources through a variety of Conservation Management Practices, in order to minimize these potential adverse impacts.

Finally, land protection goals can sometimes be best served through the designation of restricted use areas, on which management and other human activities are more tightly limited than on routinely managed areas. Such designations are appropriate on sites where the topography, hydrology, vegetation or other characteristics limit the potential benefits of active management, as well as sites where rare habitats or species have been identified and require special limits on management.

4.3 Land Management Goals

4.3.1 Goals for DWSP-Controlled Forested Areas under Active Management

- IMPROVE THE ABILITY OF THE WATERSHED FOREST TO RESIST AND RECOVER FROM DISTURBANCE (INCLUDING WIND, FIRE, INSECTS, DISEASES AND CLIMATE CHANGE).
    - CREATE AND MAINTAIN DIVERSE FOREST COMPOSITION (SPECIES, AGE, TREE SIZE, AND FOREST STRUCTURE; WITHIN STANDS AND IN THE MOSAIC OF CONDITIONS ACROSS THE LANDSCAPE).
    - MAINTAIN THE ABILITY OF THE FOREST TO ESTABLISH REGENERATION AT LEVELS OF DENSITY AND DIVERSITY THAT ARE SUFFICIENT TO PROVIDE LONG-TERM DRINKING WATER PROTECTION.
    - MAINTAIN AND ENHANCE OVERALL FOREST VIGOR.
    - ENCOURAGE LONG-LIVED SPECIES THAT ARE WELL SUITED TO THEIR SITES.
    - DISCOURAGE INVASIVE PLANTS THAT MONOPOLIZE FOREST UNDERSTORIES.
- PROMOTE NUTRIENT ASSIMILATION, FILTRATION, AND STREAM TEMPERATURE REGULATION BY MAINTAINING PLANT SUCCESSION AND VIGOROUS FOREST GROWTH.

- PREVENT SOIL DEGRADATION AND EROSION OF NUTRIENTS AND SEDIMENTS BY COMPLYING WITH OR EXCEEDING ENVIRONMENTAL REGULATIONS FOR TIMBER HARVESTING, AND BY MATCHING HARVEST SYSTEMS WITH SITE CONDITIONS.

- CONDUCT MANAGEMENT IN A MANNER THAT ENSURES THAT THE BENEFITS OF MANAGEMENT OUTWEIGH NEGATIVE IMPACTS. LIMIT REGENERATION CUTTING TO NOT MORE THAN 25% OF THE FOREST OF ANY GIVEN SUBWATERSHED DURING ANY GIVEN 10 YEAR MANAGEMENT PERIOD.

- ALIGN SILVICULTURAL OBJECTIVES WITH HYDROLOGIC CONDITIONS.

- ADDRESS SECONDARY OBJECTIVES, INCLUDING THE CONSERVATION OF BIOLOGICAL DIVERSITY WHERE THEY ARE COMPATIBLE WITH THE PRIMARY OBJECTIVES FOR DRINKING WATER SUPPLY PROTECTION.

The Division has determined that diverse, vigorous forest cover provides unparalleled water quality and should be maintained on the vast majority of its lands. The chief value of this green infrastructure is to dissipate the energy of rain and snow melt and slow the passage of water across the land and through the soils, thereby reducing erosion and allowing vegetation, soils, organic debris, and wetlands to filter out pollutants before they reach the reservoir.

In a well-maintained watershed protection forest, rain and snow are intercepted by a complex canopy structure of varying heights, densities, and tree species. Young stands vigorously capture and sequester inorganic nutrients as they grow. Impacts from exceptional rainfall or snowmelt events are moderated by the enormous infiltration and water storage capacities of forest soils rich with organic matter. Furthermore, when the ability of the forest to regenerate itself is maintained continuously, the presence and/or rapid recovery of young trees, shrubs, and herbs provides uninterrupted protection against erosion of sediments and nutrients following disturbance, even when the overstory is severely impacted. Similarly, when snow and ice damage the younger components of the forest, the maturing overstory resists this damage and provides seed to replenish the damaged understory.

The desired future condition for the watershed protection forest is a mosaic of tended and untended patches incorporating both inherent and planned diversity, which together enhance long-term forest stability. It is important to recognize that watershed forests are varied in terms of potential to sequester nutrients and excess water. Rich mesic forests adjacent to watercourses have a greater capacity than upland areas to consume nutrients and water and provide high shade. However, upland areas also require an understory and permeable soils for the maintenance of infiltration capacity. In all cases plant succession needs to proceed without excessive interference by herbivores and invasive plants in order to assure the rapid replacement of forest cover when it is reduced by disturbances.

The watershed protection forest has to cope with a wide variety of natural disturbances. Hurricanes have historically been the most catastrophic of these disturbances, although less frequent then smaller storms and insects and diseases. Plant abundance, diversity and vigor are key attributes that allow a forest to resist and recover from storms, diseases, insects, fire, human pollution and climate change. Where regeneration has been slowed by past land use practices or herbivore impacts, enrichment planting can 'jump-start' the development of abundance and diversity. Overall forest vigor is improved with treatments that favor long-lived trees well suited to their sites, thus producing a low-maintenance forest cover capable of providing perpetual, reliable filtration for drinking water sources.

The long term goal of this watershed forest management plan is to develop a highly diverse, vigorous, multiple age-class forest condition (O'Hara, 1998). This low maintenance watershed forest will make it

possible to maintain high water quality with minimal intervention. The development of such a forest at Quabbin is a long process for several reasons. Plant succession was severely impaired by excessively high deer populations for the first five decades of this water supply's history. Since the initiation of deer population control (in 1991) and the renewal of forest regeneration and general plant succession, Quabbin foresters have been able to start the process of diversifying the structure and composition of this water supply protection forest. While regeneration is now possible, the residual effects of protracted and excessive browsing will remain apparent in the absence of mid-canopy forest and the dominance of species resistant to browsing (e.g., white pine and black birch), for decades to come.

DCR's goal is to move to a multi-aged, species-diverse structure and composition as quickly as possible; the timing, however, is limited by staff size, self-imposed and general regulations on management practices, invasive plants, insects, and diseases, and the pace of plant succession and growth. The vast size of the Quabbin watershed, fluctuations in both economic and public values and uncertainties about the effects of global climate change are among the factors that conspire to make the exact timeline for achieving this goal very difficult to predict. However, this plan for the coming decade will outline objectives (section 4.2) based on our most recent experiences of what is possible and our conservative interpretation of the state of the science of watershed forest management.

4.3.2 Goals for Non-Management Areas with Forest Cover

- MAINTAIN ACCESS IN ORDER TO FACILITATE EMERGENCY RESPONSE TO FIRES, RECREATIONAL ACCIDENTS, AND TO MANAGE INVASIVE SPECIES INCURSIONS.
- PREVENT THE SPREAD OF FIRE, TO THE EXTENT POSSIBLE, INTO OR OUT FROM THESE AREAS UNLESS THESE FIRES ARE PERCEIVED TO BE BENEFICIAL.
- CONTROL THE ESTABLISHMENT AND SPREAD OF INVASIVE SPECIES IN THESE AREAS ACCORDING TO PLANS FOR INVASIVE SPECIES CONTROL ADOPTED FOR ALL DWSP PROPERTIES.
- MANAGE WILDLIFE POPULATIONS WITHIN THESE AREAS ACCORDING TO WATERSHED-WIDE OBJECTIVES ESTABLISHED FOR THESE SPECIES.
- INVENTORY AND PROTECT ENDANGERED SPECIES AND HABITATS WITHIN THESE AREAS WITH GUIDANCE FROM THE NATURAL HERITAGE AND ENDANGERED SPECIES PROGRAM.

Approximately 33% of DWSP properties surrounding Quabbin Reservoir have been identified as areas where active, conventional forest management will not occur, either because it is impractical (steep slopes, islands) or prevented by regulation (wetlands,) or because the area has been deliberately reserved from management in order to meet other objectives (Pottapaug Natural Area, portions of Quabbin Park). The goals for these non-management areas vary somewhat from site to site.

4.3.3 Management Goals for Non-Forested Areas

- ENSURE THAT THE MAINTENANCE OF NON-FORESTED HABITATS HAS NO NEGATIVE IMPACT ON WATER QUALITY, THROUGH THE USE OF STRICT CONSERVATION MANAGEMENT PRACTICES, INCLUDING THE MAINTENANCE OF FORESTED BUFFERS ALONG ADJACENT WATER RESOURCES.

- PROTECT AND ENHANCE THIS DIMINISHING HABITAT FOR SPECIES OF WILDLIFE THAT ARE CONSIDERED UNCOMMON, RARE OR UNIQUE ON A REGIONAL OR STATEWIDE BASIS.

- MAINTAIN THIS IMPORTANT COMPONENT OF THE AESTHETIC DIVERSITY OF THE LOCAL LANDSCAPE, WHERE APPROPRIATE AND NOT IN CONFLICT WITH WATER RESOURCE PROTECTION.

- PREVENT THE ESTABLISHMENT AND PURSUE THE ACTIVE REDUCTION OF ALIEN, INVASIVE PLANT SPECIES THAT MAY BE OR BECOME ASSOCIATED WITH THESE HABITATS.

- PRESERVE IMPORTANT HISTORICAL AND CULTURAL RESOURCES WITHIN THESE AREAS.

There are limited areas on DWSP-controlled properties surrounding Quabbin Reservoir that are not maintained in forest cover, including Administration Areas (parking lots and grounds around office buildings, shops and storage facilities), Recreation Areas (fishing areas, Quabbin park, scenic lookouts), Quabbin Cemetery, areas kept open as a component of the Water Supply Infrastructure (dam faces, emergency spillways), limited fields maintained for the promotion of biological diversity (fields in Gates 15, 17, 20, 29) and Rights-of-Way (power lines, public roads).

4.4 Wildlife Management Goals

- MITIGATE ADVERSE IMPACTS OF WILDLIFE ON WATER QUALITY, WATER SUPPLY INFRASTRUCTURE AND OTHER WATERSHED RESOURCES.

- PROTECT UNCOMMON, RARE, AND OTHERWISE SIGNIFICANT WILDLIFE SPECIES AND HABITATS WHEREVER THEY EXIST ON DIVISION LANDS.

- ASSESS AND MITIGATE IMPACTS OF WATERSHED MANAGEMENT ACTIVITIES ON WILDLIFE THROUGH A PROCESS OF NOTIFICATION, SITE VISITS, REVIEW OF RECORDS AND LITERATURE, AND RECOMMENDATIONS TO APPROPRIATE MANAGEMENT STAFF.

- ACTIVELY MANAGE HABITATS IN ORDER TO SUPPORT SELECTED WILDLIFE SPECIES THAT ARE CONSIDERED TO BE UNCOMMON, RARE, OR UNIQUE ON A REGIONAL OR STATEWIDE BASIS.

The primary goal of the wildlife program on the Quabbin watershed is to protect the water supply from adverse impacts caused directly or indirectly by wildlife. The Division is required by state and a federal law as well as agency mandates to protect species considered to be rare, uncommon, threatened or endangered. In general, the Division works to protect important wildlife and their habitats while minimizing or eliminating adverse wildlife impacts on other watershed resources. In certain circumstances, where applicable, active management to enhance wildlife habitat may occur.

Certain wildlife species within the Quabbin watershed can negatively impact water quality, water supply infrastructure and other critical resources in certain areas, directly or indirectly. Mitigating these impacts will be a top priority during the period of this management plan.

Broad scale, active wildlife management, especially to manage the deer population is conducted as part of this plan for the protection of the drinking water supply, Furthermore, the Division recognizes that its other land management activities may impact certain wildlife species or habitats. It is the Division's goal to avoid adversely impacting significant and especially uncommon wildlife species or their habitats while

conducting these activities. This will be accomplished primarily through inventory and survey work to locate rare species and habitats, active coordination with MassWildlife's Natural Heritage and Endangered Species Program, and proper precautions using management guidelines and Conservation Management Practices (CMP's).

While directly protecting rare or endangered wildlife will be a priority, the Division recognizes that its management activities have the potential to impact more common wildlife. Another goal, therefore, is to assess the impacts of these land management activities on the broad wildlife communities at Quabbin, and thereby minimize adverse impacts. This will be accomplished through long-term monitoring programs and an in-house review process for all planned management activities.

On certain portions of the watershed it may be feasible and desirable to proactively manage the habitat for the benefit of wildlife. This level of land management is a step beyond habitat protection and is focused on either habitats or wildlife species that are rare or of special concern on a regional or statewide basis. These management activities might include prescribed burns to enhance a field or meadow, selective removal of exotic plants, deployment of nesting platforms for certain species of birds, or the creation of brush piles or rock piles for cover in suitable habitat.

4.5 Biological Diversity Protection Goals

- MAINTAIN AN UNDEVELOPED, FORESTED CONDITION ON MOST OF THE DIVISION'S LAND HOLDINGS.
- WORK TO IDENTIFY ALL UNCOMMON OR RARE SPECIES PRESENT ON DIVISION LANDS, AND PROVIDE HABITAT CONDITIONS AND LEVELS OF PROTECTION RECOMMENDED FOR PERPETUATING THESE SPECIES.
- MEET OR EXCEED STATUTORY REQUIREMENTS FOR THE PROTECTION OF THESE SPECIES, INCLUDING THOSE IN THE FEDERAL ENDANGERED SPECIES ACT OF 1973 AND THE 1990 MASSACHUSETTS ENDANGERED SPECIES ACT, AS WELL AS THE 1986 WILDLIFE HABITAT AMENDMENT TO THE MASSACHUSETTS WETLANDS PROTECTION ACT.
- MAINTAIN LIMITED ACREAGE OF EARLY SUCCESSIONAL FORESTED AND NON-FORESTED HABITATS ON DIVISION LANDS AT QUABBIN (SEE SECTIONS 5.2.3.9 AND 5.5.4.3) .
- IDENTIFY AND CONTROL INVASIVE SPECIES ON DIVISION PROPERTIES.
- MAINTAIN FOREST RESERVES ON A PORTION OF THE DIVISION'S HOLDINGS.

The Division's greatest single contribution to regional biodiversity is the maintenance and management of large areas of undeveloped, forested habitat. Forests can contribute to soil and water conservation, and provide habitat for a range of indigenous plants and animals, aesthetic values, and recreational opportunities. The protection from development that results from DCR ownership contributes significantly to the long-term viability of a variety of organisms and natural communities.

Rare and uncommon species contribute to the biological complexity of a landscape or region. Efforts to identify and protect rare or endangered species or habitats occur continually on Division land. In 2000, the University of Massachusetts, Department of Natural Resources Conservation provided a report to the Division on rare, unique, and exemplary natural communities on the Quabbin watershed. Future studies

to locate and classify rare natural communities may be initiated. Actions to protect and enhance these species and habitats will provide critical protection of important components of biodiversity.

The Division owns several hundred acres of non-forested habitat including administrative areas, former plantations that were converted to fields in the 1980s to increase water yield, and scrub/shrub meadows. Some of these habitats will be maintained in an early successional stage through mowing and/or the use of fire in order to provide habitat for an array of organisms that depend on non-forested areas. As discussed previously, in order to ensure biological representation of indigenous species, a range of habitat conditions must be present. Early successional forested habitat has been clearly identified as a rare habitat type within the state (MassWildlife, pers. comm., Dettmers and Rosenberg 2000). By its nature, early successional forested habitat is dynamic both spatially and temporally. It must either be continually created or maintained at that successional stage or it will mature into older forest. Even-aged forest management techniques will be used to create and/or maintain this habitat in selected portions of Division holdings, following careful review of proposed area.

Invasive species are commonly recognized as a major threat to native flora and fauna and biodiversity. In extreme cases, invading exotics can out-compete and exclude native vegetation, resulting in a monoculture of the invasive plant. The result is a tremendous loss of native plant and associated animal diversity. The Division will strive to identify, control and where possible, eliminate invasive species from Division lands, within the limits imposed by water quality protection or limitations of resources and personnel.

The primary reason for incorporating forest reserves into land management planning is to ensure representative examples of biodiversity indigenous to an area are protected (Norton 1999). Forest reserves are important because they contribute to the full range of biodiversity and are important to a wide spectrum of species requiring undisturbed habitat. In addition, forest reserves can act as a reference or "control" site in which to assess the impact of management activities. Reserves also provide a different aesthetic opportunity and have a different character than managed forests. The Division has set aside a series of small and larger reserves totaling in excess of 10,000 acres within the Quabbin properties, as detailed in Section 5.5.4..

4.6 Cultural Resources Protection Goals

- IDENTIFY SIGNIFICANT CULTURAL RESOURCES ON WATERSHED LANDS.
- PREVENT DEGRADATION OF CULTURAL SITES AND RESOURCES.

Cultural Resources are part of our collective heritage and human experience, and are often fragile and non-renewable. The goal of Federal and State preservation legislation, as well as that of the DCR Cultural Resource Management Program, is to protect cultural resources out of respect for the past, for the education and enjoyment of future generations, and for the insight these resources may provide into our long-term relationship with our surroundings.

5 Management Plan Objectives and Methods: 2007-2017

5.1 Land Protection

5.1.1 Land Acquisition

5.1.1.1 1985-2006 Land Acquisition Program

The three active Division watersheds have been included in the land acquisition program since its inception in 1985. While a preponderance of the available acquisition resources have been used to acquire acreage on the Wachusett Reservoir watershed (highest priority), sensitive lands have also been protected on the Quabbin Reservoir and Ware River watersheds. The purpose of the land acquisition program is to acquire sensitive watershed land and to protect it from urbanization and then to restore and/or maintain stable forest cover on this land. Few sites already developed or significantly disturbed are acquired. Instead, relatively undisturbed lands are purchased as a preventative measure, countering potential threats to water quality that would result from development of these lands.

To help determine which parcels would provide the greatest water quality protection for the money spent, the former MDC/DWM developed land acquisition models, first for the Wachusett and then, in 1998, the Ware River watershed. Land in and around tributaries, aquifers, and wetlands will contain the greatest proportion of a basin's water at any given time. Studies of small New England watersheds emphasize the importance of low lying, water-rich areas in contributing the majority of runoff during storm events through saturated surface and subsurface flow (Dunne and Leopold, 1978, and Hewlett and Nutter, 1969). As a precipitation event continues, the area contributing to saturated flow increases. It is believed that this "variable source," however severe the storm event, includes less than half the watershed area. Pollutants introduced to these water-rich sources are more likely to impact tributary water quality than those introduced on non-source areas.

Land Protection Highlights:

1. The Commonwealth, from 1995 to 2004, has acquired 368 acres for watershed protection on the Quabbin watershed, bringing the total holdings to 54,311 acres.
2. **Payments in lieu of taxes** for Quabbin watershed towns are approaching $1.8 million/yr
3. DWSP **technical assistance to landowners and communities** aids watershed protection efforts. Since 1995, 5,323 acres of private forestland were enrolled in Stewardship via $63,058 of DWSP funding, about $1/acre/yr.
4. The 160 miles of **boundary** associated with the DWSP Quabbin holdings are maintained every 10 years. The 289 acres of utility rights-of-way are subject to site-specific controls and utilities are required to submit 5-year and yearly plans for their management.
5. Seven **Watershed** Rangers are assigned to Quabbin/Ware River and tasked with rules education and pro-active surveillance patrols, as well as emergency response for both legal and illegal access to the DWSP properties. Domestic animal and human trespass are the most common interventions.
6. **Wildfires** occur 2-3 times per year at Quabbin and are generally held to less than 10 acres in size. The local Fire Chief directs DWSP crews, who have received regular training in fire control. Fire fighting equipment upgrades and maintenance of access roads provide further improvement in Division fire response.
7. **Watershed security** received additional focus after the events of September 11, 2001 and the Bioterrorism Act of 2002 required Vulnerability Assessments, delivered for Quabbin in September 2003. Among the changes are the closing of sensitive access points, background checks for research permits, better gate management, among many others.

Protecting large tracts of land in a small state like Massachusetts is not easy. Massachusetts has the third highest population density in the country and developmental pressures and competing uses for open space areas are high. The biggest threat to biodiversity in Massachusetts is fragmentation of habitat caused by development. Land conservation is an important tool in dealing with water conservation, biodiversity and habitat protection, and open space fragmentation.

Unlike the Wachusett and Ware River watersheds, the Quabbin watershed has not yet been modeled to determine land protection priorities. DCR control of Quabbin watershed acreage stands at 56.9% - much higher than the other active watersheds. Rather, Quabbin subwatersheds have been prioritized for land protection decision making. **Table 34** shows these subwatersheds and their current protection levels for both DCR lands and other protected open space.

Table 34: Open Space Protection in Quabbin Basins with Acquisition Opportunities

Subwatershed	Total Acres	Total Open Space	DCR Controlled	Other Open Space	% Protected
West Branch of Swift River	14,845	10,427	9,012	1,415	70.2
Fever/Hop Brooks	21,158	15,110	12,986	2,124	71.4
East & Middle Branches of Swift River	34,761	13,220	6,977	6,243	38.1
TOTAL	**70,764**	**38,757**	**28,975**	**9,782**	**54.8**

Source: DCR/DWSP, 2007

From 1995 to 2004, the Commonwealth has acquired, for watershed protection, 368 acres on the Quabbin watershed, bringing the total holdings to 54,311 acres, or 56.9% (up from 54.3% in 1985) of the watershed. Expenditures for this acreage total $1.292 million. Funding for the watershed land acquisition program since 1985 has come from the 1983 Open Space Bond ($3 million); the 1987 Open Space Bond ($30 million); and the Watershed Protection Act of 1992 ($135 million).

As DCR/DWSP pursues new land acquisition funding options, DWSP will concentrate on purchasing land on the Wachusett watershed, which is the least protected basin, with 26% under Division control. Efforts will continue, however, toward purchasing a number of previously identified key parcels throughout the Quabbin Reservoir and Ware River watersheds.

5.1.1.2 Future Land Acquisition Objectives

Future land acquisition in the Quabbin Reservoir watershed is expected to be limited and very selective, given the expected available funding and the fact that much of the watershed is already protected lands. Particular emphasis will be given to projects that address the acquisition of inholdings in order to consolidate boundaries, and conservation restrictions on prioritized parcels that, when protected, will prevent adverse changes in land use considered a significant threat to water quality by the Land Acquisition Panel (LAP). Gifts, bargain sales, and partnering opportunities in land acquisition will contribute to a more favorable prioritization status.

The Quabbin watershed is divided into three priority zones for land protection, based on travel time data (pollutant fates), and proximity to aqueduct intakes. The primary zone is the West Branch of the Swift River. The secondary zone is the Hop Brook, Fever Brook, and Middle Branch tributaries. Tertiary status is given to the East Branch of the Swift River.

5.1.1.3 Payments In-Lieu of Taxes (PILOT) Program

5.1.1.3.1 PILOT Program Description and Legislation

The DCR Division of Water Supply Protection, Office of Watershed Management PILOT program annually monetarily compensates the communities that contain the land and water bodies that comprise one of the nation's largest unfiltered water supply systems. The Payment in Lieu of Taxes program guarantees regular and stable payment to 31 communities (see **Table 35** for the 11 towns within the Quabbin Reservoir watershed).

The PILOT program is mandated by Massachusetts General Laws ch. 59, § 5G . This legislation updated old payment laws MGL ch. 59, §§ 5D-5F, which were written in the 1940s, and did not value lands in all communities currently entitled to payments. The current PILOT law was first ratified in 1984 for the Quabbin Reservoir and Ware River watersheds. The law was amended in 1987 to include communities in the Wachusett Reservoir and Sudbury Reservoir watersheds.

5.1.1.3.2 PILOT Funding

Money for the Office of Watershed Management PILOT program comes from the Massachusetts Water Resources Authority (MWRA) rate payers who use the reservoir waters. They pay their water bills to the MWRA, which provides DCR with the funds needed to make the PILOT payment. DCR makes the annual payment in full to each community in the program. This program is solely for lands managed for drinking water supply by the Office of Watershed Management. All other state-owned lands that are eligible for payments in lieu of taxes under MGL ch. 58, §§ 13-17 are reimbursed, subject to appropriation, by the legislature through state aid to municipalities (the "cherry sheet").

5.1.1.3.3 PILOT Amounts

The Department of Revenue (DOR) revalues state-owned land every four years. The most recent DOR revaluation assessed all property owned in-fee by the Commonwealth as of 1/1/2005. The revaluation takes into account all lands purchased by the state over the previous five years as well as any changes in land values. The new values took effect in FY2006.

The PILOT amount is determined by multiplying the Department of Revenue valuation of DCR Division of Water Supply Protection land by the highest local property tax classification (regardless of actual land classification). Most PILOT land is forested, but the PILOT calculations use the same rate structure as commercial or industrial property. Legislative provisions state that the Office of Watershed Management PILOT payment can never be less than that of the previous year, even if the value of the land or tax rates decrease.

DCR works diligently with the watershed communities, MWRA, and DOR to comply with the PILOT law. **Table 35** demonstrates that the PILOT program provides substantial revenue to the watershed communities. MGL ch. 59, § 5G also dictates that five Quabbin Reservoir watershed communities (Belchertown, Hardwick, New Salem, Pelham, Petersham and Ware) receive a second payment for lands annexed from the disincorporation of the former towns of Dana, Enfield, Greenwich, and Prescott. The amount received from this second payment totaled $429,360 in FY2007, representing 31% of the total PILOT received by these five towns. The 2007 "Independent State Auditor's Report on the Department of Conservation and Recreation and the Massachusetts Water Resources Authority Compliance with Watershed Agreement Requirements" (Commonwealth of Massachusetts, Auditor of the Commonwealth, No. 2007-0276-3C, Boston, MA August 2007) specifically noted that "there is no apparent reason for making PILOT payments twice for the same piece of land," however any change in this payment process will require legislative action. Legislation was proposed in January 2007; however at the time of publication no final action has occurred to amend the PILOT law.

Table 35: Payment-in-lieu of Taxes FY05-FY06, Quabbin Reservoir Watershed Communities

Community	PILOT FY2005	PILOT FY2006	% TOTAL PILOT+
Barre	$129,668	$129,668	2.2%
Belchertown*	$170,786	$171,883	2.9%
Hardwick*	$54,761	$54,761	0.9%
New Salem*	$264,481	$264,481	4.5%
Orange	$3,286	$3,286	0.1%
Pelham*	$162,276	$186,864	3.2%
Petersham*	$338,978	$338,978	5.7%
Phillipston	$7,067	$7,067	0.1%
Shutesbury	$250,019	$250,019	4.2%
Ware*	$320,224	$320,224	5.4%
Wendell	$16,247	$16,247	0.3%
Total Quabbin Watershed	**$1,717,793**	**$1,743,478**	29.5%
Total PILOT+	**$5,076,573**	**$5,919,709**	

Source: (DCR/DWSP, 2006)

* Includes payments for land annexed by town after disincorporation of communities for Quabbin Reservoir.

\+ Distributed to 31 communities in the Quabbin Reservoir, Ware River, Wachusett Reservoir, and Sudbury Reservoir Watershed Systems

5.1.1.4 Land Disposition Policy

DWSP regularly comes under pressure from both private and municipal parties for disposition of parcels of its lands for purposes that may be inconsistent with drinking water supply protection. While there are certain areas of land ownership throughout the water supply system that may not be of critical importance to water supply protection, these areas require careful scrutiny prior to disposition. DWSP will consider land disposition only under exceptional circumstances for private or municipal uses. DWSP will not promote the use of watershed lands for purposes that are inconsistent with goals for water quality protection. The proponent of the disposition must demonstrate that resources of greater value will be protected either through acquisition of Article 97 land or through other means, so that the missions and legal mandates of DWSP are protected and enhanced.

The Watershed Land Disposition Policy, approved in April, 1998, provides a framework for the agency to properly discharge its obligations to protect the water supply and to protect the Commonwealth's broader interests in open space protection under Article 97 of the Constitution of the Commonwealth. The intent of the policy is to provide additional watershed-specific instructions to the Executive Office of Energy and Environmental Affairs on disposition of Article 97 lands. DWSP follows EOEEA's land disposition guidelines and DWSP is extremely stringent about agreeing to land dispositions and will pursue them only if the disposition can be a benefit to the Commonwealth and the protection of our water resources.

Disposition Procedures

1. All reviews of Article 97 land disposition requests by DCR/DWSP shall be consistent with *EOEEA Article 97 Land Disposition Policy*.

2. A written request shall be submitted to DCR/DWSP for disposition of a particular parcel.

3. If the disposition request is proposed by a municipality, it shall appoint a committee to initiate the DCR/DWSP review process.

4. DCR/DWSP shall provide copies of EOEEA and DCR/DWSP Article 97 land disposition policies to the proponent and, if applicable, to members of the municipality's appointed committee.

5. The proponent shall submit an EOEEA-approved Open Space and Recreation Plan (M.G.L. c.41 §81D) to DCR/DWSP.

6. Alternatives to disposition of the Article 97 land shall be evaluated for prioritization based on their impact on the water supply, criteria provided by DCR/DWSP and the municipal committee, and local interests. DCR/DWSP staff may provide guidance to the municipal committee, if possible.

7. The proponent shall comply with the requirements of the Massachusetts Environmental Policy Act (MEPA) as it relates to disposition of Article 97 land. This includes requirements for disposition of parcels of two acres or more, and those proposed uses which would have significant traffic impacts (M.G.L. c.30 §61-62).

8. The proponent shall comply with all applicable state and federal laws and regulations, including the state and federal Rare and Endangered Species acts (M.G.L. c.131A, 16 U.S.C. §1531), Historic Preservation Acts (M.G.L. c.9 §§26-27C), Wetlands and Rivers Protection Acts (M.G.L. c.131 §40, 33 U.S.C. §1251, et.seq.).

9. The proponent shall demonstrate that resources of equal or greater size, resource value, and fair market value will be protected, as determined by DCR/DWSP and EOEEA, either through acquisition of additional Article 97 land or through other means, so that the missions and legal mandates of DCR/DWSP and EOEEA are protected and enhanced. Any disposition may affect future Payments In Lieu of Taxes (PILOT) to a municipality.

10. Upon receipt of all relevant documentation, DCR/DWSP shall review the disposition request. If approved, the request shall be forwarded to the DCR Lands Committee and the DCR Commissioner. The Commissioner has the jurisdiction over the disposition of DCR/DWSP managed lands, and has the authority to approve or overrule the recommendation of DCR/DWSP.

11. Following approval by the DCR Lands Committee and the Commissioner, the disposition request shall be sent to the Secretary of EOEEA and the Commissioner of the Massachusetts Division of Capital Asset Management (DCAM) for their approval.

12. Following approval by all required state agencies, the proponent shall provide a registered survey plan, including the metes and bounds of the parcel.

13. Any disposition, whether by lease or fee, shall include language which causes the land to revert to the Commonwealth if the land is not used for the approved purpose or the proponent does not adhere to the terms and conditions of the disposition agreed to by the proponent and DCR/DWSP. Any disposition shall include transfer of land of equal or greater size, resource value, and fair market value. If a disposition involves replacement real estate land of lower fair market value, the difference in fair market value between the replacement parcel and the subject parcel must be paid to the DCR Water Supply Protection Trust.

14. The proponent shall identify a legislative sponsor who shall submit Article 97 land disposition legislation for approval by the General Court.

5.1.2 Protection of Private and Community-Owned Lands

5.1.2.1 Conservation Restrictions

In addition to direct land acquisition, DCR/DWSP has been protecting land within the watersheds by using cost effective conservation restrictions to protect land from development while simultaneously encouraging private landowners to continue to practice effective stewardship on their properties.

A conservation restriction (CR, also called a conservation easement) is a legal agreement a property owner makes to restrict the type and amount of development that may take place on his/her property. A property owner agrees to sell or donate limited rights to their property to a state agency or nonprofit land conservation agency. The landowner remains the owner and retains all rights to ownership except those described in the conservation restriction.

There are both conservation and monetary advantages to landowners who sell or donate CRs. Neither landowners nor the purchasing organization/agency of a CR can develop the land in ways prohibited by the deed. Furthermore, landowners are paid not to develop their property. After the sale of a CR, the property is assessed at a lower value due to its development restrictions, which in turn reduces the landowner's property taxes and possibly estate taxes as well. If the CR is donated for conservation purposes, it also generates an income tax deduction. Consultation with a qualified estate planner is strongly recommended by DWSP so that landowners clearly understand the specific benefits of a CR on their property.

Once recorded, a CR remains in effect for future owners should the landowner decide to sell the property. Future owners are bound by the restrictions within the CR. CRs are usually permanent and in order for a CR to qualify as a tax-deductible charitable gift, it must be granted in perpetuity. A popular alternative to putting an owner's entire property under restrictions is to work with the acquiring agency to survey the area to be placed under the CR, while excluding any area that the owner wants to remain unrestricted. Often the owner's house and outbuildings will be excluded from the CR.

DCR/DWSP pursues the acquisition of CRs as well as fee acquisitions for the purpose of water and watershed protection. There is no PILOT obligation to DCR from a CR because the land remains as private property. Each CR is tailored to the interests of the owner and DCR. It is the policy of DCR/DWSP to purchase CRs that will not conflict with water quality protection. Typical use restrictions include construction of buildings or utilities, septic systems, paving, dumping, excavating, mining, use of pesticides, storing hazardous materials, and certain agricultural purposes. Continued use of the property by its owners for forestry, wildlife, recreation and privacy purposes is encouraged.

Once DCR/DWSP purchases a CR, it assumes the responsibility for conducting a baseline survey of existing conditions. A staff person will photo-document the entire property, prepare maps and gather as much information about the property from the owner as possible. It is very important to document what uses were in effect at the time of the acquisition. Permissible uses are also generally transferred with new ownership when CR property is sold. In the spirit of conservation, DWSP will require that any items that may be inconsistent with the provisions of the CR be removed when land owners are able, such as junk cars, appliances, or other waste debris. A yearly inspection is conducted to ensure that the purposes of the CR are being maintained. DCR/DWSP will work with a landowner to help prevent negative impacts, such as abutter encroachments and unauthorized recreational access, and will also help provide technical assistance for managing these lands.

DCR/DWSP currently holds 54 CRs across the Quabbin, Ware River, and Wachusett watersheds. These CRs total 3,533 protected acres. Most CR owners are individuals. However DCR has also purchased CRs from sportsman's clubs, golf courses, and municipalities. There are 10 DWSP CRs, totaling 715 acres on the Quabbin Watershed.

5.1.2.2 Technical Assistance to Communities

In the Commonwealth of Massachusetts, municipalities have significant authority over land use and development. Towns are authorized to enact and enforce a variety of statutes, including zoning bylaws, subdivision bylaws, and overlay districts (such as aquifer protection bylaws). In addition, the state delegated partial authority for regulations such as Title 5 and the Wetlands Protection Act to municipal governments.

Volunteer boards, such as the local boards of health, conservation commissions, and planning boards, are responsible for these bylaws and regulations. Tasks that board members must perform include reviewing proposals, determining if the applicable standards are met, issuing approvals or permits, and supervising construction and other on-site compliance reviews. In many towns, especially small ones, there are few paid professional positions, and the boards may not have town staff to support them. Further, the board members may or may not have received training in that technical area. DWSP's community technical assistance program seeks to maximize the watershed protection afforded under locally delegated controls by offering its expertise and resources to support local officials' decision making.

DWSP historically has maintained contact with local boards through the review of major development proposals, construction site inspections, and other situations pertaining to compliance with state and federal regulations. Through these efforts, the agency has helped to address a range of water supply pollution sources, such as septic systems, sedimentation from construction, road drainage, stormwater runoff from residential area, and recreational field runoff. DWSP's involvement in local planning and environmental issues was greatly expanded with the passage of the 1992 Watershed Protection Act (WsPA). The WsPA specifically required a program of technical assistance to affected communities that includes, but is not limited to, "planning studies, and zoning bylaw studies, health bylaw studies and subdivision by-law studies" (Chapter 36 of the Acts of 1992, §15: regulations included in **Appendix II**).

The DWSP Technical Assistance Program encompasses the following types of activities:

1. Growth management planning, master plans, and land use studies.
2. Review, revision, and development of by-laws, subdivision and other regulations, protective districts, and performance standards.
3. Refinement of local monitoring, review, permitting, and enforcement practices.
4. Design advice to municipal boards or landowners from natural resource, engineering, and planning professionals.
5. On-site reviews of proposed development projects with local board members and municipal officials.
6. Public education programs.
7. Applied watershed management research.
8. Technology transfer.
9. Coordinating program topics and audiences with other technical assistance organizations (such as watershed associations).

The Technical Assistance Program provides the watershed communities three different avenues to obtain help with their local land use regulatory needs:

1. **Board Communication:** Attendance at local board meetings is an effective way to foster good communication between DWSP and the watershed communities. DWSP presence offers both regulatory review and the opportunity to provide immediate technical assistance and, if need be, the recommendation for more in-depth consultation.

2. **In-House Projects:** There are some instances where a town requires more than a conversation to help with a project. In cases where DWSP staff have time and resources, the agency provides in-

house support. Projects that the Quabbin Environmental Planning staff have worked on are included as **Appendix V.**

3. **Technical Assistance Contracts:** There are many land use planning projects that communities want to initiate that are beyond their financial means. Throughout the 1990s, DWSP, upon the request of a watershed town, would support a study or plan if finances were available. A critique of these efforts was that the funds were distributed on a first-come, first-serve basis and that some towns were not obtaining this financial support. The 1998 Watershed Protection Plan for Wachusett Reservoir and the 2000 Watershed Protection Plan for Quabbin Reservoir identified the need for a competitive program to distribute Technical Assistance contracts. Staff established a process that was implemented in FY2002, distributing over $150,000 throughout the watershed system, including funding for Master Plans in Petersham and Shutesbury, as well as septic system site analyses in New Salem and Wendell. Unfortunately these funds were a casualty of subsequent budget restrictions. A relatively small amount of funding ($16,000) was identified in FY2007 and was used to provide reference materials and training opportunities to town Planning Boards, Conservation Commissions, Building Inspectors, Zoning Boards of Appeals, and Boards of Health. Due to the success of this initiative, the Division will continue to utilize these funds, when available, for efforts that further support the work of local boards in their creation, interpretation, and implementation of laws that promote water quality protection.

By working with watershed area officials and citizens, DWSP can successfully find common ground on resource protection issues. These projects help both local resources and the Metropolitan Boston water supply. The technical assistance program emphasizes local source protection and its immediate impact to watershed residents and decision-makers. Through this cooperative approach, DWSP improves the land-use planning, control of development, and general environmental protection at the local level, which ultimately benefits drinking water source protection. It is, however, the town's responsibility to adopt and implement any plan or bylaw.

5.1.2.3 Technical Assistance to Private Forest Landowners

In 1994, private forest lands on the Quabbin and Wachusett Reservoir watersheds and the Ware River watershed totaled in excess of 95,000 acres. In 1995, DWSP started its Private Lands Forestry Program to provide funding for private forestland owners to complete 10-year management plans for these forests, in an effort to forestall development of these parcels. Letters were sent to private consulting foresters informing them that clients whose properties fell within the water supply watersheds were eligible for 100% funding of the cost of producing management plans, using current requirements of the Forest Stewardship Program in order to secure Chapter 61 property tax abatement if they desired, or to access incentive funds available for practices.

Over the course of the 12 years that the program has functioned, the agency has provided $63,058, with which we have enrolled a total of 5,323 acres in Stewardship and/or Chapter 61 for ten-year periods, at an average cost of $12 per acre (or just over $1 per acre per year). This acreage is divided among 71 parcels, with an average parcel size of 75 acres. **Table 36** shows how these acres are distributed by watershed.

Table 36: Private Lands Forestry Assistance

Watershed	# of Parcels	# of Acres	Average Parcel Size	Total Cost
Quabbin	22	2,170	99	$25,697
Wachusett	35	2,275	65	$26,908
Ware River	14	879	63	$10,453
TOTAL	**71**	**5,323**	**75**	**$63,058**

The Executive Office of Energy and Environmental Affairs identified this type of program as critical to

long-term protection of the Massachusetts landscape, and has subsequently dedicated funding to a comprehensive, statewide private forest lands program through the Massachusetts Forest Stewardship Program. To avoid redundancy, DWSP has suspended its own private lands assistance program.

5.1.3 Boundaries

The total length of the boundary that encompasses DCR/DWSP holdings surrounding the Quabbin Reservoir is 160 miles, of which 4 miles abut private in-holdings and 8 miles abut the Shutesbury State Park in-holding. DWSP property boundaries are the "front line" of watershed protection, in that they are immediately adjacent to private land on which DWSP's watershed protection principles may or may not be followed. The protection provided by boundaries is therefore enhanced by regular maintenance to keep them visible, and by immediate identification and resolution of encroachments.

5.1.3.1 Maintenance of Boundaries

Maintenance of DWSP boundaries is a straightforward but daunting task. Before maintaining boundaries, DWSP engineering and forestry staff must first determine their exact location in the field, accounting for recent land acquisition and its effects on the adjacent and outermost boundaries. Once accurately relocated, these boundaries are kept visible by the forestry staff on a regular 10 year cycle, primarily by clearing brush along the line and repainting blazes. This regular perambulation of the boundaries also serves to identify encroachments (see Section 5.1.3.2).

5.1.3.2 Encroachment Discovery and Response

Encroachment by abutters onto the Commonwealth's properties has become a significant problem across DCR watersheds. This is due in part to development pressures, occasional unclear boundaries and a lack of monitoring and enforcement. Some of these encroachments are minor (e.g., mowing onto Commonwealth property), while others are quite significant (e.g., re-grading, landscaping, or placing structures directly on DCR property).

Most encroachments are discovered by field staff (civil engineers and foresters) while performing routine boundary marking or surveying of areas where boundary lines are unclear. Once an encroachment is identified, a series of letters and field inspections are required in order to ensure compliance with the actions recommended by DWSP. Through experience, the Division has determined that the best method for preventing new encroachments is by swift, effective, and fair resolution of those that are discovered. A small number of encroachments need to be resolved through court actions that require a great deal of additional police and DWSP staff time. DWSP strives whenever possible to resolve encroachments outside of the court.

5.1.3.3 Cooperation with Abutters

Division staff work hard to educate abutters about the agency's objectives for watershed protection. As the largest landowner within the Quabbin watershed, it is extremely important for the Division to maintain a good relationship with abutters to DWSP property. Setting a good example of proper land stewardship for neighboring property owners may positively influence an owner's actions on their own property. By having a good relationship with abutters, it is more likely that neighboring landowners would report unauthorized uses or encroachment problems that may occur on DWSP land.

Section 42 of Chapter 132 of Massachusetts General Laws, also known as the Forest Cutting Practices Act, includes the following requirement for notification of abutters:

> Every owner of land who proposes to cut forest products on land devoted to forest purposes, or to cause such products to be cut, except as provided in section forty-four, shall send by certified mail or hand deliver written notice of his intention to begin any cutting operation to the abutters of record on file with the assessors of the town in which

the land lies, and whose closest boundary is within two hundred feet of the edge of the cutting area, at least ten days prior to operations

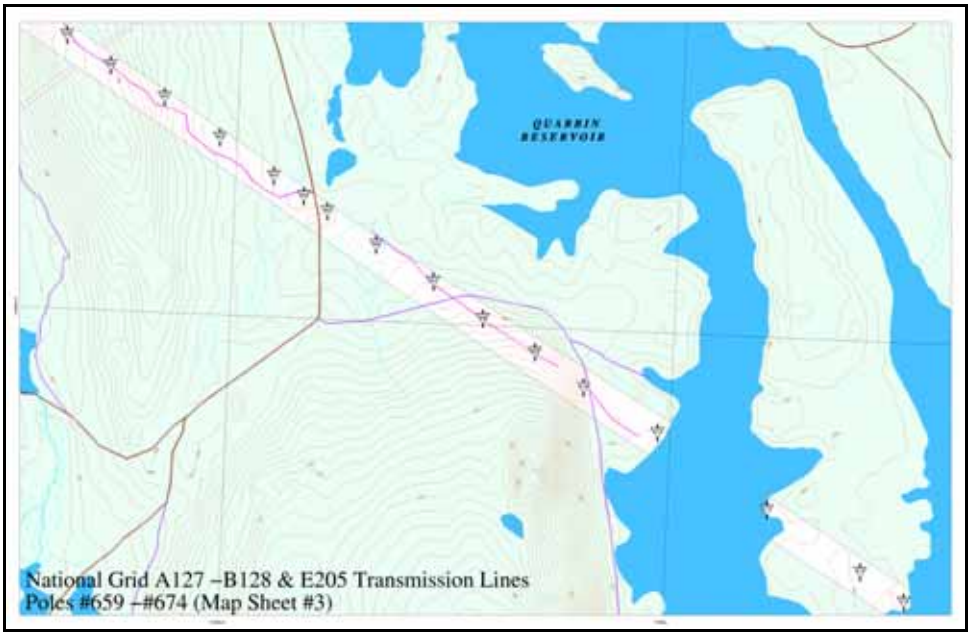
The majority of the DWSP properties at Quabbin are greater than 200 feet from adjacent, privately-held lands, so that notification is not required. However, the Division does notify abutters when harvesting on portions of the property that abut within 200 feet.

5.1.3.4 Rights-of-Way

DCR maintains site-specific watershed protection controls within the approximately 289 acres of rights-of-way (ROW) of utilities, railways, and highways crossing the Quabbin Reservoir Watershed. These controls are designed to minimize risks to water quality associated with the maintenance and use of these corridors in the watershed. Power line ROW are typically vegetated and maintained in a constant state of early succession to prevent contact with the wires, which could cause possible disruption of service*. In order to conduct this maintenance, utilities in Massachusetts are directed by 333 CMR 11.00, Rights-of-Way regulations administered by the Massachusetts Department of Agricultural Resources, to develop and submit for approval five year, Vegetative Management Plans (VMP) and Yearly Operational Plans (YOP).

As part of the approval process, DCR specifically reviews and comments on the planned activities to apply herbicides to control vegetation†. Resource identification (public surface water supplies) and associated "no spray" and limited zone delineation on maps and in the field is the focus on this review. A sample "T-sheet" that identifies the power line ROW in relation to the water resource appears below (**Figure 13**). These maps were developed by DCR staff to aid in the YOP review process prior to field visits. Monitoring is primarily targeted at buffer zone maintenance documentation and reporting. Over the past five years, DCR staff have also been contributing to the update of 333 CMR 11.00. The final version of these regulations was adopted in March, 2007.

Figure 13: Sample "T-sheet" for Powerline ROW



* Powerlines in the eastern US have been found to constitute a potential reservoir of shrubland habitat for birds species that breed in early-successional shrubland habitats (King, 2002).
† Review was also conducted under 1997 MOU between DAR and MDC. This MOU was revoked by DAR on 12/6/06.

5.1.4 Public Education

5.1.4.1 Role of DWSP Watershed Rangers in Land Protection

The Division controls about 42% of a 257,000-acre watershed and reservoir system, which provides drinking water for nearly 2.2 million people. Public access to this system is determined by regulation and policy. Physical barriers such as gates help to prevent inappropriate uses throughout the watershed. For several decades prior to 1992, the Metropolitan Police, who had jurisdiction in any town that contained Division property, patrolled the watershed system. In 1992, the Metropolitan Police force was consolidated with the State Police and local police departments. A Memorandum of Understanding was established with the MA State Police to provide the same services to the Division watersheds that were carried out by the former Metropolitan Police. Following the consolidation, the MDC felt it would be prudent to create a limited ranger program to complement the efforts of the MA police, including rangers specifically assigned to watershed protection. MGL Ch. 92, s. 34b specifies the authority of these rangers:

> The Metropolitan District Commission is hereby authorized to establish a park ranger program within the department to preserve, maintain and protect the parks, reservations, historic sites and open space and to ensure the environmental integrity of properties under the care, custody and control of the commission.

Within the Mission Statement of DCR Park Ranger Unit (which includes Watershed Rangers), four primary objectives are identified:

1. Resource Protection: Park Rangers will provide active and visible uniformed patrols of DCR properties and facilities in an effort to discourage improper use and criminal activity. Park Rangers issue verbal or written warnings and non-criminal citations to individuals who violate DCR Rules and Regulations and contact the MA State Police to address criminal activity.
2. Visitor Services: Park Rangers will assist visitors to DCR properties by providing them with information as requested, rendering emergency service when necessary, and promoting educational and recreational opportunities through various programs and activities.
3. Education and Community Relations: Park Rangers will encourage appreciation and proper use of DCR resources through various outreach programs. This includes maintaining an active working relationship with park visitors, user/friends groups and the owners of private properties abutting DCR lands.
4. Reservation and Historic Site Management: Park Rangers will assist in proper maintenance and protection of properties and facilities by implementing measures for damage prevention, conducting routine on-site inspections, promptly reporting and documenting maintenance problems, and taking and documenting corrective action.

The primary function of the Division's Watershed Rangers is to protect drinking water resources by conducting regularly-scheduled patrols of the watersheds. Watershed Rangers provide a visual, uniformed presence on Division lands and pro-actively patrol to help prevent problems, such as vandalism, inappropriate recreation uses, illegal dumping and accidents within the watershed that may degrade water, forest, wildlife and/or cultural resources. The Rangers rely on rules education rather than enforcement to seek compliance. Rangers do not have law enforcement powers. When situations occur that require law enforcement personnel, Watershed Rangers communicate these to the State Police and other enforcement agencies. In addition, the MA Environmental Police provide rules enforcement for complementary state wide environmental regulations. Watershed Rangers are in radio contact with both the EPOs and State police and meet systematically with both these groups. These relationships are critical to the enforcement of DCR regulations.

Since 1999, DCR Watershed Rangers have kept records of their access rule enforcement interventions. **Table 37** shows the total rules interventions by type from 1999-2005.

Watershed Rangers are "good will ambassadors" and not only show a positive presence but also speak on behalf of the agency and the Division about proper watershed stewardship and drinking water protection to community or other organization gatherings, children, school groups, service organizations, senior groups, etc. Through their positive interaction with visitors, rangers protect these open spaces and encourage all people to do the same by obeying all watershed rules and regulations for specific Division reservoirs and the system as a whole.

Watershed Rangers provide security for Division facilities and other designated buildings, and regularly monitor potential trouble spots on the watershed. Special use and group permits may be checked by Rangers to ensure that permittees are in compliance with their permit. Rangers keep a daily log of their patrolling activities. Incidents are documented and are referred to the appropriate authorities. Rangers also aid in placement of signage on Division lands throughout the watershed, to assure the public has ample opportunity to become informed about access regulations.

Since 1996, the number of Rangers assigned to the Quabbin/Ware River watersheds has grown from one to seven. Ranger patrols include pro-active surveillance of DCR/DWSP-owned lands with emphasis on popular access locations around the Quabbin watershed. Rangers monitor and report on the condition of trails and signs, ice conditions, and illegal activities such as dumping of trash and debris, illegal vehicle use, fires, swimming, and removal of natural or cultural resources. In addition, Watershed Rangers are trained as emergency first responders and have undertaken ice rescue training.

Table 37: Quabbin Watershed Ranger Interventions, 1999-2005

Intervention Type	Number of Rule Interventions
Domestic Animals	919
Trespass	896
Bike/Sled/Ski	215
Swim/Wade	161
Boating	122
Fishing	98
Snowmobiles/ATV/M.V.	61
Cooking/Fires	51
Vandalism	47
Dumping/Littering	47
Alcohol	38
Metal Detecting	15
Permit Violations	15
Collecting	14
Firearms/Target Shooting	3
Disorderly Conduct	2
Harassment/Breach of Peace	3
Non-compliance	1
Feeding Wildlife	1
Parasailing/Aircraft Landing	2

Source: OWM Watershed Rangers, 2005

5.1.4.2 Interpreting Land Protection/Management Priorities

Public education is a vital component of the Division's watershed management and protection programs. The Division strives to directly communicate not only what the access rules and regulations are and why they are necessary, but also what the land protection and management priorities are and how and why these are implemented. To this end, different sections work on different fronts of public education and interpretative services. The Watershed Rangers speak informally with users while patrolling property. The Quabbin Visitor Center Staff conduct school programs for students within watershed communities, maintain the Quabbin Visitor Center and related programs. In addition, the Forestry and Natural Resources staffs regularly provide field tours to academic institutions from around the world who are interested in the application of watershed forest management principles on the Quabbin watershed.

5.1.5 Fire Protection

DCR DWSP is committed to protecting the watershed forest, as well as watershed visitors, from the impacts of forest fires. While light burns in forest areas without forest regeneration cause little harm, hotter fires, especially in areas with younger forests, can cause serious impacts including death of both understory and overstory trees and exposure of mineral soil over large areas, causing an increased potential for overland flow, erosion, and nutrient loading. Two fires in the 1950s at Quabbin (one north of Route 122 and one on the Prescott Peninsula) were of this nature, killing significant areas of understory and overstory vegetation. All fires can endanger the visiting public and adjacent landowners.

Forest fire frequency over the last decade has decreased to approximately 2 to 3 incidents per year and these have all been <10 acres in size. Nearly all recent wildfires at Quabbin have been caused by the visiting public and were associated with illegal campfires or improper disposal of smoking materials. DCR/DWSP has implemented the recommendations of the 1986 Forest and Wildlife Management Plan, including:

- Strictly enforcing the prohibition against landing of boats on islands and the shoreline of the reservoir.

- Eliminating all public access to the Reservation during times of extreme fire danger conditions.

Through increased education and enforcement efforts, DCR/DWSP has reduced the number of illegal boat landings. A water protection policy was initiated which set up designated landing areas with portable toilet facilities. This action resulted in less beaching of boats in unauthorized areas and allowed for much better control of the visiting public.

DCR DWSP did close the watershed to public access during a brief period in October, 1984 due to extreme fire danger conditions. In a March, 1994 meeting between the then DEM and MDC, it was agreed that during periods of extreme fire danger, the two agencies would cooperate to provide trained personnel to keep fire watch from the tower at Mt. Grace in Warwick State Park. This site provides an excellent view of Quabbin and is best situated for triangulation with the Pelham and Princeton towers. [The 2003 merger of MDC and DEM into DCR resulted in two forestry related sections within the same agency. DWSP's foresters are solely responsible for watershed management lands, while the Bureau of Forestry serves both public and private lands, including the oversight of fire control.]

Other recommendations of the 1986 Quabbin Forest and Wildlife Management Plan which have been implemented include:

- Improve cooperation with local fire departments.

- Improve forest road conditions in areas of poor access and high fire hazard and risk.

- Implement a fire watch during extreme fire situations.

Due to the decrease in incidents, increased cooperation with area fire personnel and the relatively wet fire seasons experienced over the last decade, the recommendation "Training of Division staff in fire suppression" has been modified to include training in the Incident Command System (ICS) and in hazardous materials spill and boom deployment. Hazardous spills pose a greater risk to the water supply and it has been determined that this is a better use of limited training time.

Since 1986, the Division has made measurable improvements in many of the above areas. A fire policy was drafted in 1987 and has been improved and updated as recently as June, 2006. This policy specifically outlines the steps necessary for suppression of wildfires on DCR lands.

Through constant communication with town fire departments and DCR's Bureau of Forestry fire control personnel, the Division has improved the coordination of fire suppression. Effective coordination with local fire departments is critical as the local Fire Chief is the person legally in charge of a fire fighting operation. DCR/DWSP's role is to assist the local fire department and to assume responsibility only at the direction of the local fire chief (usually for "mop up" operations). The addition of a radio system at Quabbin that is linked to DCR Bureau of Forestry fire control personnel has greatly improved communications during wildfires.

Extensive progress has been made in the repair and maintenance of the forest road system at Quabbin over the years. This has improved access to most areas of the watershed (see next section for detailed report on roads). The Division has also acquired fire fighting apparatus that improves its readiness in fighting fires.

During the management period from 2006-2015, DWSP will develop a communication plan that addresses the inter-operability of the DCR radio system with local and state agencies. This plan will be part of the larger emergency operations plan being developed for the section.

The DWSP will also finalize the Watershed Emergency Access Map that highlights road intersections, boat launching sites, and helipads. This map will be distributed to local and state Police, Fire, EMS, Underwater rescue, and hazmat units which may respond to an incident on the watershed.

5.1.6 Security and Emergency Planning

The terrorist attacks of September 11, 2001 forced all public water suppliers to focus their attention on the security of the water supply. Security of the water system must be comprehensive – source to tap – but flexible enough to adjust to a range of potential threat conditions. The Division's policies are periodically reviewed in order to achieve the goal of providing a safe and secure water supply system.

Following "9/11", the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (Bioterrorism Act) was passed into Federal Law (PL 107-188). Section 401 of that act amended the Safe Drinking Water Act (SDWA) by adding section 1433(a), which requires all community public water systems (including military installations) serving 3,300 people or more to conduct Vulnerability Assessments (VAs), certify to EPA that the VAs were conducted, and submit a copy of the VA to EPA. The DWSP worked with the MWRA to complete a VA for the water supply systems under its care. This VA was completed and submitted to US EPA for the entire water system on September 30, 2003.

As a result of this Vulnerability Assessment, the Division implemented short-term and long-term changes to its land management practices, as follows:

Short-term land management changes included:

- Closing public access to the Winsor Dam and other critical assets.
- Placing Jersey barriers across roadways with temporary fencing around potentially vulnerable areas.
- Blocking utility right-of-way access routes to unauthorized motor vehicles.
- Staffing check points by MA National Guards and MA State Police at main entrance points and Gate 17, and requiring staff id and other forms of identification.
- Suspending forestry and research access temporarily, while procedures were established for improving security checks on permit holders.
- Temporarily suspending access to fishing areas and other recreational use areas while the potential threat associated with these areas was evaluated.

Long-term land management changes included:

- Closing vehicle access to the Winsor Dam and Goodnough Dike.
- Prohibiting general public access around CVA Intake and Shaft 12 buildings including new fencing, locks, and signage.
- Enhancing Watershed Ranger patrols throughout the watershed.
- Requiring background checks for all research permits.
- Improving gate management, including numbering, inventory, and physical modifications to gates.
- Establishing an access management system with permits.

DWSP will continue to develop and refine its approach toward domestic incident management to prevent, prepare for, respond to, and recover from terrorist attacks, major disasters, and other emergencies.

5.2 Management of Forested Lands

5.2.1 History of Quabbin Watershed Forestry 1930 – 1960

5.2.1.1 Land Taking and Development for Water Supply

With signing of Chapter 321 of the Acts of 1927, the Quabbin Reservoir project had official approval to begin work. The bulk of the land purchasing in the Quabbin Reservation came with the "General Taking" of March 28, 1938. The "General Taking" is defined by the "fire line", a 40 foot clearcut swath along the DWSP boundary. Besides land taking, the agency was busy constructing dams, dikes, aqueducts, roads, highways, buildings, a power station, and Quabbin tower, and clearing the 24,000 acre reservoir and planting trees on 10,000 acres of open land. Most of this work was done in a period of 10 years. During this time, two major floods and a catastrophic hurricane occurred.

The clearing of 24,000 acres of all trees, and the subsequent flooding, impacted the Swift River Valley by eliminating most of the pine types, both white and pitch, all of the small ponds, miles of streams and significant wetlands. The clearing process created huge amounts of waste wood (slabs, branches etc.), which had to be removed; the only practical way was through burning. In the process of burning the debris, most of the present islands and hundreds of acres along the Reservoir shore and most of Quabbin Hill were extensively burned. These woodland fires stimulated the development of hardwood sprouts and seedlings throughout the burned areas. Tremendous amounts of deer food were produced by both the clearing and burning. Although the fires burned hot and killed small trees, they did not kill larger overstory trees. An exception was a later fire in 1957 which did kill the overstory. This fire was just north of Route 122 in New Salem and resulted in the death of 100 year old pines and hemlocks on 400 acres.

Forest Management Highlights:

1. Early forest management (1930-1970) at Quabbin focused on planting of 6,760 acres, pruning, limited non-commercial thinning, and extensive commercial improvement thinning. This was followed first by clearing of plantations to improve water yield (1980s), and then by deer herd reduction and small group selection silviculture to produce diverse forest structure (1990s to present).
2. From the approximately 47,000 acres considered to be actively managed at Quabbin, just over 1,000 acres has been treated annually since 1960. In recent years, about 400 acres of the treated area has been regenerated annually to form new age classes.
3. Forest management guidelines include cutting no more than 25% of the stocking of any given subwatershed in any given 10 year period and strict adherence to conservative Conservation Management Practices.
4. Harvesting is also limited by hydrologic zones based on proximity to water resources. Regeneration openings in Zone 1 will not exceed ½ acre; Zone 2 will not exceed 1 acre; and 90% of Zone 3 openings will not exceed 2 acres, while 10% will be larger.
5. Efforts to build diversity in size/age classes and in species composition are designed to build resistence and resilience in the face of disturbances ranging from wind and heavy snow/ice to diseases, insects, and climate change.
6. Management plan review, annual internal review of proposed harvesting and roadwork, and post-harvesting summary reports and public meetings provide wide-ranging internal and public review of DWSP forest management practices.

The construction of two large earth dams required huge amounts of soil. This resulted in the development of several open pit mines adjacent to the Reservoir and the stripping of 2-3 feet of top soil from most fields on agency lands in the town of Ware. Most stripped areas were planted to conifers. These plantations have shown the effects of soil loss, often including disease, stunted growth, and frequent wind-throw.

During World War II, the military established a presence at Quabbin with a firing range at the south end of Little Quabbin and several bombing and strafing ranges for aircraft. Most of this activity had little impact on

the land except for fires started by 100 lb. practice bombs. Many bombs ended up a considerable distance from the targets, and one of these ignited a fire that burned 2,000 acres of the northeast corner of Prescott Peninsula. It was a hot ground fire fueled with blow-down from the 1938 hurricane. The fire crossed several roads before topography and wetlands stopped its spread. The fire opened the forest, fostering the production of an understory of hardwood sprouts and seedlings.

In the first years after it acquired watershed lands, the MDC harvested forest products to provide for its own lumber needs. A private sawmill owner could bid on sawing a certain amount of lumber for the agency. Sawmills would be set up near the forest where the trees were to be cut. During the late 1940s and through the 1950s at least four cuttings were made to meet these needs. In addition, several private timber sales were conducted in the 1950s both inside and outside gated areas of the Quabbin. Prior to 1960, the total volume of timber removed by these cutting operations after MDC attained care and control of the properties was less then 5 million board feet (excluding hurricane salvage).

5.2.1.2 Establishment and Management of Plantations on Open Lands

A forestry program for the reforestation of open land and of areas growing brush was initiated in 1934 for the better protection of the watershed, with the goal of establishing a revenue-producing watershed forest. Coniferous trees were chosen for the following benefits:

- Prevention of the growth of deciduous trees so that leaves are kept from entering the water and undesirable color and taste produced by decomposing organic material is minimized.
- Reduction of the force of heavy rains through dispersal of rain drops into a fine spray by the coniferous foliage, thereby increasing the absorption of precipitation by the soil.
- Control of snowmelt in the spring due to the dense shade beneath the coniferous canopy as opposed to the rapid melting and evaporation that takes place in open areas and in deciduous forests.
- Conservation of soil moisture in deeper soils due to the shallow rooting of conifers.
- Fast growth of coniferous trees and the value of the quality timber they produce.
- Ability of conifers to grow well on a wide range of sites.

Red pine was specifically favored because it was resistant to blister rust and white pine weevil, was easily grown in the nursery, and survived transplanting well. During the period from 1935 to 1946 approximately 8,243,600 pine trees were planted on roughly 6,760 acres of open land. These areas consisted of:

- Arable land. This land grew agricultural crops for human consumption or forage for feeding domestic animals. When agriculture declined much of this land was used as pastureland. Most of the soils consist of fine sandy loams such as the Charlton series.
- Pasture land. This is land on which domestic animals had been pastured, but it was open land, not pastured woodland. The majority of these soils were moderately well-drained fine sandy loams such as the Scituate series.
- Sproutland. This land had dense shrubby vegetation or trees of seedling or sapling size. The land had recently (1 - 15 years) been withdrawn from agricultural use and was not cut over woodland.

Many of the 6,760 acres of original plantation failed, generally by succumbing to competition from native species. Plantations survived beyond the establishment stage on approximately 3,200 acres. Trees were

planted in straight rows, mostly five feet on center. This "five-by" spacing insured a rapid closing of the crowns in order to prevent the development of large branches on the lower portions of the trees, produce straighter stems, and eliminate much of the danger of insect damage.

With this spacing, crown closure occurred within 15-20 years. At this point, these stands were to receive some kind of silvicultural treatment such as a thinning. This did not happen due to lack of labor and available markets. As a result of overcrowding and competition for water and nutrients, growth rates in many stands became stagnated. The stands remained stagnated, except for a limited number that were commercially thinned in the late 1950s. During the 1960s, approximately 630 acres of plantations were pruned and 730 acres received some type of pre-commercial thinning. In most instances, these operations occurred simultaneously.

The decade of the 1970s saw a move from non-commercial to commercial silviculture, and thinnings occurred on about 800 acres of pine plantations. During this period the region experienced a drought and water quantity became a great concern. Ongoing studies on the Cadwell Creek experimental watershed and others showed that water yields could be increased by lowering the stocking of the forest and that greatest increases in yield occurred when the forest was completely removed from a watershed area. With water yields as the goal, approximately 400 acres of stagnated or diseased plantations were clear-cut and converted back into fields during the decade of the 1980s. This figure was considerably less than the 3,000 acres of plantation clearings that were outlined in the 1986 Forest Management Plan (the difference between the planned and actual removals was due to the need for careful supervision of private contractors and the limited number of available contractors).

During the 1980s, both intermediate and regeneration cuts continued, covering approximately 900 acres of plantations that decade. While many of these plantations were on hardwood sites, white pine regenerated well in most instances but hardwood regeneration was very limited due to deer browsing. Toward the end of the decade, MDC management philosophy changed with respect to pine plantations, when water conservation measures proved successful and the need to increase water yields was no longer a primary concern. Today, DWSP's principal concerns with its pine plantations are to maintain their ability to protect water quality, by increasing structural and species diversity and by replacing high risk stands (growing on wetter soils) through natural regeneration with native species more likely to persist on these sites.

5.2.2 Objectives and Accomplishments of Previous Quabbin Management Plans

5.2.2.1 Hunt's 1961 Assessment

The first "management plan" for the Quabbin forest was actually a Master's thesis written by MDC Forester Fred M. Hunt in 1961 and titled "Forest Resources on the Metropolitan District Commission Lands Surrounding Quabbin Reservoir." The management objectives outlined in this thesis were:

- Provide, through Continuous Forest Inventory (CFI), detailed information on the condition of the forest so that the forest manager could carry out sound management practices designed to improve the productivity of the watershed for both water and timber values.

- Determine through a study of the literature on the subject, the types of vegetative cover that would best suit the needs of this particular watershed.

- Develop, for each of the major timber types on the area, management procedures that would produce the types of cover determined above.

The recommendations necessary to meet these objectives were put forth in this document. The inventory, present condition of the forest, characteristics of good watershed cover and recommendations for watershed management were discussed in detail. Ideal forest conditions for the watershed were described as forest

composed of native species that were long-lived and suited to the site conditions. White pine, red oak, hemlock and white ash best fit these criteria. The forest would be of moderate stocking, have good growth and quality and include equal areas in each age class. This forest would promote a forest floor that allowed precipitation to rapidly infiltrate the soil and would enhance both aesthetic and wildlife values.

The recommendations were to conduct commercial silvicultural operations on 10,560 acres and remove approximately 35 million board feet of timber. Much of this work would be salvaging trees that had been partially damaged by the 1938 hurricane or trees which were of poor health, vigor and quality. Several thousand acres of non-commercial silviculture was also recommended, primarily in dense pine plantations and hardwood stands that had regenerated from the 1938 hurricane. These cutting practices were designed to improve stand health and where possible to allow regeneration to develop. Deer browsing was considered to be inhibiting forest regeneration on much of the reservation.

The recommendations of the plan were closely followed and a total of 32.5 million board feet was harvested on approximately 9,000 acres of watershed. Although a few hundred acres of non-commercial silviculture was completed with MDC personnel, this work stopped in 1964 when the workforce was assigned to maintenance of the Quabbin Park area.

During this decade a significant drought occurred and the Quabbin Reservoir dropped 34 feet below full elevation, the lowest level since its construction. The role of forest management in defending against such dramatic drops became an important topic of discussion.

5.2.2.2 Spencer/Walker 1972 Quabbin Watershed Management Plan

The first official MDC management plan was prepared by Bruce Spencer and Charles Walker in 1972 and titled "Watershed Management Plan for Metropolitan District Commission Lands Surrounding Quabbin Reservoir." The objectives of this plan were:

- Create and maintain an additional water yield of 10% annually from the Quabbin Reservation.
- Improve the health and quality of the Quabbin forest.
- Maintain healthy populations of native wildlife.
- Maintain, improve and protect an aesthetically pleasing landscape.

This plan followed and expanded upon most of the recommendations of Hunt's thesis. It also urged hiring more personnel to better care for the watershed. The condition of the forest was determined from inventory data collected from the remeasurement of several hundred permanent Continuous Forest Inventory plots (CFI). The implementation of silvicultural activities was detailed, especially commercial logging activities. Logging systems and methods to eliminate significant impacts to water, forest, wildlife and aesthetics were outlined. The watershed was zoned for forest management, administrative uses, and natural areas.

Deer still prevented regeneration on large areas of the watershed but the recommendation was to delay corrective action for 15-20 years, acknowledging that the absence of regeneration might enhance water yields. However, this plan stressed that a solution to heavy deer browsing be found at the end of that period, to compensate for the maturation and gradual break-up of the overstory.

Beaver, introduced in 1952, were spread throughout the entire watershed by 1972 and responsible for creating approximately 1,200 acres of ponds and marsh. Although the damage to forests and road culverts from beaver was noted, the benefits to other wildlife were also mentioned. Beaver management was recommended only where the road system was threatened.

The plan recommended silvicultural operations on 12,000 acres of natural stands, thinning 3,000 acres of pine plantations and clearing 500 acres of stagnated and diseased pine plantations. Thirty one million board feet of timber was expected to come from these operations.

During the plan period, silviculture was conducted on 9,500 acres, yielding 20.5 million board feet of timber and 30 thousand cords of firewood. Approximately 75 acres of pine plantations were salvaged and cleared due to storm damage or disease. A new demand for firewood allowed thinning of overstocked stands that had been scheduled for work by MDC crews in the first plan. Only a small amount of thinning was done in pine plantations because there was little commercial demand for the wood and no budget to pay for non-commercial thinning. The difference between planned and completed work during this decade highlights the importance of market conditions in accomplishing necessary work.

5.2.2.3 Spencer/Lyons 1986 Quabbin Watershed Forest and Wildlife Management Plan

The second MDC management plan was prepared by Bruce Spencer and Paul Lyons in the early 1980s. The plan was titled "A Ten Year Forest and Wildlife Management Plan for the Quabbin Watershed." The objectives of this plan were:

- Identify and protect critical, sensitive, rare or otherwise valuable habitat.
- Thin forest stands to reduce stocking levels to 20-40% (i.e., savannah forest) or 60-70% (i.e., "thinned forest").
- Convert several thousand acres of conifer plantations to open grass cover.
- Plant important wildlife food/cover species.
- Diversify wildlife habitat conditions on the Reservation using a variety of other management practices.

These objectives supported the primary goal of increasing water yields while maintaining water quality and vigorous forest and wildlife communities. The plan strongly supported the addition of more MDC personnel to better care for the watershed. The plan expanded the discussion on all aspects of management such as the landscape design aspects of watershed management, methods of determining the recommended harvest, and a discussion of the dynamics of water yields.

The goal of striving for multiple age classes of native species suited to site conditions was reiterated, although browsing and associated herbaceous competition (ferns, barberry, and assorted others) had prevented and would continue to prevent the development of new age classes on 2/3 of the hardwood forest. The need for regeneration to replace the forest following a disturbance was again discussed.

Specific recommendations were made to work on 23,000 acres (20,000 acres of silvicultural practices and 3,000 acres of pine plantation conversions to fields) and harvest 33 million board feet, 150,000 cords and 400,000 tons of chips (red and white pine plantations).

The actual acreage worked was 11,450 acres from which 13.8 million board feet, 39,000 cords of firewood and 141,600 tons of whole tree chips were harvested. Of the 3,000 acres of pine plantations to be converted to fields, 400 acres were actually completed. Although the pines could have been marketed and MDC would have realized income from this project, contractors with the proper equipment were not available.

The firewood market collapsed in the last half of the decade and therefore much of the hardwood thinning was not completed. The creation of savannah forest via harvesting, which would then be maintained through

deer browsing, was discontinued. It was felt that water-rich areas produced similar yields regardless of whether the vegetation was mostly ferns or trees.

Additional staff and equipment were added to better care for the watershed and to maintain the roads and forest. Some roads had become an erosion problem due to insufficient staff and equipment. With a combination of new equipment and personnel plus monies from timber sales to supply gravel, trucking, culverts, gates and other equipment and supplies, much of the forest road mileage was restored to good condition. Equipment to operate within pine plantations while avoiding damage to walls, foundations, and advance regeneration was purchased for operation by MDC personnel. The purchase and installation of additional gates to control access was also accomplished. Starting in the last half of this management period, an action plan to solve the deer problem was implemented.

Table 38 presents the number of acres treated since the 1960s. A decline in acres treated in the 1980s was due to the decreasing ability of the forest to regenerate, changes in forest product markets, and the assignment of forestry staff to other projects including forest inventory, management plan preparation, boundary marking, and land acquisition.

Table 38: Acres of Silvicultural Treatment by Fiscal Year, 1960-1995

Year(s)	Acres treated	Year(s)	Acres treated
1960s	9,000	1987	645
1970s	9,500	1988	1,232
1980	2,202	1989	940
1981	1,037	1990	404
1982	1,831	1991	722
1983	1,598	1992	507
1984	1,369	1993	704
1985	1,512	1994	945
1986	1,169	1995	786

5.2.2.4 MDC Quabbin Land Management Plan 1995-2004

The third Quabbin Land Management Plan was prepared shortly after the initiation of deer impact control through public hunting (in 1991) and just before the management of these lands became the first public land management in North America to receive “green” certification from the international Forest Stewardship Council (in 1997).

The 1995-2004 plan identified both short-term (10 year) and long-term (60 year) objectives. The primary objective in the short term was to manage for the recovery of tree regeneration, a component of the forest structure that had been severely restricted for fifty years due to uncontrolled expansion of deer browsing. This objective was to be met through a combination of reductions in the size of the deer population and specific forest management practices, such as preparatory cuttings and enrichment plantings. The long-term objectives were to bring about the development of a multi-aged, species-diverse forest that was determined to be the most stable cover for this drinking water supply, especially in the face of potential large-scale disturbances by wind, ice damage, or insects and disease, among others. Long-range objectives also included a proposed effort to identify priority areas for treatment based on a “sub-basin” analysis, to determine which areas had the greatest influence on water quality. The plan also called for the creation of a Scientific and Technical Advisory Committee to assist Division staff in setting priorities for management.

The first objective of the plan, to reduce deer impacts, was addressed very successfully during the 1995-2004 period, and this success continues today. Deer populations across the watershed were reduced to

levels that allow tree regeneration to become established and begin to grow into new age classes. The specific silvicultural objective was to regenerate one-third of approximately 1,500 to 2,000 acres treated per year, or about 500 to 600 acres regenerated annually. **Table 39** details the silviculture that was actually completed during the decade of this plan, which averaged 388 acres regenerated annually from a total of approximately 1,000 acres treated.

Table 39: Harvesting Summary for FY1995 through FY2005

Fiscal Year	Total Acres Harvested	Total Acres Regenerated[1]	Board Feet	Cords	Tons	Revenue
1996	659	85	2,645,494	1,994	3,458	$306,048
1997	1,274	682	7,447,357	3,495	9,215	$727,993
1998	1,253	385	4,894,431	4,908	1,569	$677,017
1999	1,332	382	5,327,581	4,974	7,410	$567,504
2000	1,110	419	5,042,700	3,884	6,221	$1,028,977
2001	745	371	4,532,600	2,703	8,059	$524,075
2002	808	380	4,196,880	2,646	7,665	$571,601
2003	1,003	397	5,575,799	4,150	8,645	$704,882
2004	890	337	2,873,334	4,095	5,170	$381,540
2005	1,205	439	5,146,694	5,598	6,864	$757,708
TOTAL	**10,279**	**3,877**	**47,682,870**	**38,447**	**64,276**	**$6,247,345**
Average	*1,028*	*388*	*4,768,287*	*3,845*	*6,428*	*$ 624,734*

[1] Note that the regeneration objective was to regenerate approximately one third of each harvesting sale area, unless the treatment was exclusively intermediate thinnings. The difference between harvested area and area regenerated is intentional and does not imply regeneration failure.

5.2.2.5 Regeneration Changes during the Previous Management Period

Regeneration has been systematically and intensively monitored on the Quabbin Reservoir watershed since 1989 and throughout the previous management period. A summary of results from this monitoring is included as an Appendix to this plan, entitled "2004 Quabbin Regeneration Summary Report." Shorter updates are produced by DWSP annually, to serve as the backdrop for annual deer impact control management programs (see summary of deer program results in Section 5.4.4.4.). The deer impact control program that is in place has been very successful in reaching DWSP goals for the re-establishment of regeneration potential and diverse plant succession throughout even the most heavily impacted areas of the watershed. **Table 40** provides a comparison between the conditions encountered in the regeneration surveys conducted in the late 1980s and early 1990s and the conditions recorded in the most recent watershed-wide intensive regeneration survey.

White pine and black birch regeneration beneath thinned red pine plantation on Prescott Peninsula

Table 40: Regeneration Comparison 1989, 1994, 2004

Area / Block	Year	Stems per acre 1' to 4.5' tall	Stems per acre >4.5' tall	TOTAL
Off Reservation	1989	1,960	1,140	3,100
	1994	2,750	1,840	4,590
	2004	2,071	1,404	3,475
On Reservation	1989	770	130	910
	1994	2,955	417	3,372
	2004	3,187	1,344	4,531
Hardwick	1994	1,840	581	2,421
	2004	2,634	1,333	3,967
New Salem	1994	3,846	212	4,058
	2004	3,399	950	4,349
Pelham	1994	930	71	1,001
	2004	2,102	901	3,001
Petersham	1994	4,369	1,054	5,423
	2004	4,438	2,008	6,446
Prescott	1994	3,789	167	3,956
	2004	3,267	1,331	4,598

5.2.3 DCR/DWSP Quabbin Forest Management Objectives 2007-2017

DWSP has concluded that the forest conditions that best meet the combined objectives of the agency – to deliver predictable quantities of high-quality drinking water at a reasonable cost while protecting the fullest possible suite of associated natural resources – include vigorous trees of broad, site-suited species composition and age classes well-distributed across the watershed and capable of rapid regeneration and active growth following a wide range of both natural and deliberate disturbances. This conclusion was reached through critical review of past and current research literature, consultation with an extensive array of academic and field professionals in natural resources management and related disciplines, and more than four decades of direct experience with watershed forest management. The conclusions of the agency have been open to critical and timely revision by the public that is served by these objectives. Throughout this management period DCR will continue to solicit public input as adaptive revisions are proposed during annual progress reviews, based on additional experiences and changing objectives.

Note that the objectives listed in the following sections refer to those areas of the DWSP holdings around Quabbin Reservoir that are actively managed, an area that includes approximately 46,000acres. These objectives specifically exclude those areas that are identified as reserved from management, as described in Section 5.5.4, Areas with Special Management Restrictions, and totaling approximately 12,000 acres.

5.2.3.1 Primary Objectives

The primary objective of forest management of the Quabbin forest is to create and maintain a complex forest structure, which forms a protective forest cover and a biological filter on the watershed land. This watershed protection forest is designed to be vigorous, diverse in species and age, actively accumulating biomass, conserving ecological and economic values, actively regenerating, and most importantly maintaining a predictable flow of high quality water from the land.

From 1960 to 1990, the primary objective of forest management at Quabbin was to maintain vigorous forest growth through silvicultural thinning and stand improvement harvests. Regeneration of all species was not possible throughout much of the Quabbin until the successful deer impact management program that began in 1991. Regeneration potential is essential to restore the forest cover as quickly as possible following any disturbance and to enable the deliberate creation of diverse age classes. Based on results from past surveys, the primary regeneration objective of this plan is for areas that have been deliberately regenerated to contain an average of at least 2,000 trees per acre greater than 4.5 feet in height, of a diverse mix of species appropriate to the site, within 3-7 years of the disturbance This management plan will be the first of five plans to work with an actively regenerating forest throughout the Quabbin reservation, enabling the gradual fulfillment of our watershed protection forest structure objectives.

The present Quabbin forest overstory originated as stands that regenerated following farm abandonment from 1850-1900 and subsequent cutting, or by stands that regenerated following the hurricane of 1938 and by the deliberate planting of trees on agricultural fields at approximately the same time, so that the range of overstory ages is generally between 65 and 160 years of age. During the past decade, the Division has successfully regenerated approximately 3,900 acres, or 8.5% of the actively managed forest (approaching the objectives of the 1995-2004 Quabbin Land Management Plan to regenerate approximately 1/3 of the managed forest every 30 years).

Converting the present day even-aged forest stands into a multi-aged forest is a long process (Kelty, et al, 2003) that will not be fully implemented for many decades, and will most certainly be disrupted by frequent small and infrequent large disturbances. The guiding objective for silviculture during the decade of this plan will be to regenerate approximately 1% of the managed forest annually, so that by the end of the decade, an additional 10% of the managed forest will have been converted to a new age class. Large, unmanaged stands that will include individuals and groups of trees living to biological maturities ranging from 100 to 400 or more years of age, will, barring major disturbances, continue to be a component of the

watershed protection forest surrounding Quabbin Reservoir..

The managed forest that was regenerated in the past decade was distributed throughout the forest types and origins, with some emphasis on replacing failing pine plantations established in the late 1930s (some of these plantings were established on sites not suited to their long-term growth and development). Managing the mix of stands from the 1930s and those from an earlier time has required the application of varied silvicultural systems. Generally, stands dominated by long-lived trees, well suited to the site, have been treated with uneven-aged silvicultural methods ranging from single tree to small group selection harvests (up to one acre in size). In stands dominated by trees not suited to the site, various methods within the even-aged silvicultural system have been used to more rapidly regenerate these stands to trees better suited to the site conditions. The vast majority of the Quabbin forest is currently occupied by species growing on suitable sites.

Over the next decade, the Division intends to refine its silvicultural techniques while continuing to implement the primary objectives stated in the previous plan. Silvicultural practices will work to maintain or enhance species diversity. Age structure will become more diverse. Approximately 1% of the managed forest will be regenerated annually to create a new age class. The majority of the harvesting will focus on regeneration openings ranging from single-tree to small group selections (less than one acre in size) and patch cuts up to 2 acres in size. On a limited basis, larger openings will be implemented to more rapidly regenerate some areas and to meet green certification recommendations to enhance landscape-level horizontal forest diversity. Full details of the proposed zoning and silvicultural approach are included in Section 5.2.3.3.

The Division will consider the current condition of individual management units (such as the presence of significant insects or diseases), and inventory the condition of the access network (roads, staging areas) in order to plan for upgrades as necessary and limits on the size and type of equipment that can operate the area. Areas with special management restrictions, such as rare species habitats or cultural features requiring heightened protection, will be identified, and then the specific silvicultural prescription will be proposed through the annual Lot Review process (see Section 5.2.7).

5.2.3.2 Subwatershed Administration of Forest Management

While the focus of DWSP's mission is the overall condition of the watershed and the quality of the water in the reservoir, those conditions reflect the collective conditions of a group of smaller drainages, or subwatersheds that comprise the whole. The planning process for land management, public recreation, and other watershed activities is therefore most logically done on a subwatershed basis.

Historically, records on forest management activities on Quabbin Reservation have been based on a "compartment" system. 94 compartments were established on the reservation, usually bounded by roads, streams, the reservoir shoreline, or other obvious natural features. As new lots were sold and operated, their locations and other pertinent information were added to maps and tables for each compartment, first manually and later by computer.

While this system has proven useful for record-keeping purposes, it does not allow for the efficient monitoring of land management activities on a drainage area basis. However, with the advent of Geographic Information Systems (GIS), Global Positioning Systems (GPS), and high-quality digital orthophotos of the watershed, it is now possible to efficiently keep track of our management work by hydrologic units or subwatersheds.

5.2.3.2.1 Quabbin Subwatersheds

A subwatershed is defined in most cases as the land area that drains to a perennial tributary of the reservoir. Drainage areas were delineated using the MassGIS watershed delineation tool, starting from

the point where the tributary met the reservoir. In most cases, these were 2nd or 3rd order streams. Where those tributaries represent higher-order streams or rivers however, they were further subdivided. This process resulted in the identification of 56 subwatersheds on Quabbin (**Figure 14**). There are areas within the watershed, and in particular along the shorelines, that drain directly to the reservoir via subsurface flow rather than via a distinct tributary. These areas are not distinct subwatersheds flowing through a unique collection point at the reservoir's edge, but are critical direct drainage areas that lie immediately adjacent to the reservoir.

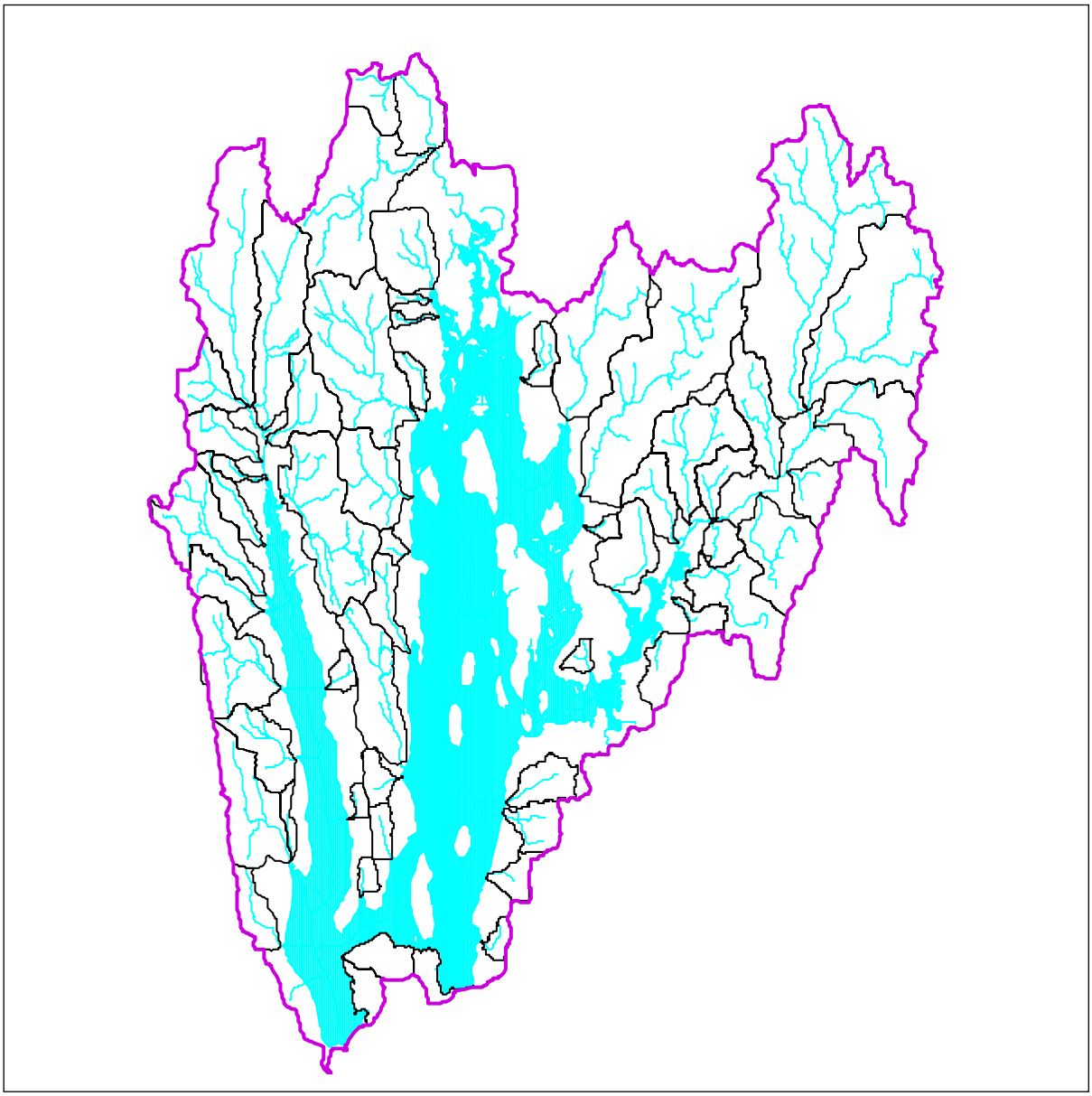


Figure 14: Subwatersheds and direct drainage areas within the Quabbin Reservoir watershed

5.2.3.2.2 Implementing Subwatershed-Based Planning

The general theory behind the use of subwatershed-based planning is to control the proportion of a drainage area that is "disturbed" by management activities (e.g., logging or roadwork) during the management period in order to reduce the chances of water quality impacts. This approach is partly based on research on experimental watersheds throughout the eastern US that indicate that until approximately 25-30% of the watershed forest overstory stocking is harvested (assuming nearly 100% forest cover type),

there is a no detectable increase in water yield (Hornbeck and Kochenderfer, 2004; Hornbeck et al., 1993). As increases in transport of sediments and nutrients to tributaries and the reservoir are directly related to increases in water yield, it follows that the 25-30% threshold also applies to water quality changes (so long as Conservation Management Practices are in place, the greatest concern is with the movement of nutrients rather than sediments; see Section 5.2.5). The same research also demonstrated that water yield generally returns to pre-harvest conditions as the harvested area regenerates – usually within 3-10 years.

Once drainage areas have been delineated and the locations of harvest operations have been digitized, the GIS provides straightforward techniques to estimate the percentage of a subwatershed forest that has been harvested in any given time period. That information will be available to DWSP Foresters before they propose their logging operations for the coming year. Where the forest stocking across any given subwatershed has been reduced during the previous decade by an amount approaching 25-30% of full stocking, further harvesting in those drainages will be postponed. This percentage may be estimated based on the area of regeneration openings versus the total area of the subwatershed, or through stocking estimations.

While the 25-30% figure provides a guideline for meeting water quality standards, other factors, such as soil types, topography, proximity of the management work to water courses, and the concentration and distribution of the harvesting can affect the decision about acceptable levels of harvesting. Another consideration in subwatershed-based planning is the proximity of a subwatershed to the water intake structures. Those subwatersheds that are far removed from the intakes could be considered less sensitive to management effects than those in close proximity. In each individual instance, subwatershed–based recommendations will be tempered by best professional judgment.

To facilitate the use of subwatershed information in land management planning, maps of each subwatershed will be produced, showing boundaries, topography, soils, roads, and locations of logging operations conducted during the past 10 years. Foresters will then consult these subwatershed maps prior to planning their coming year's work.

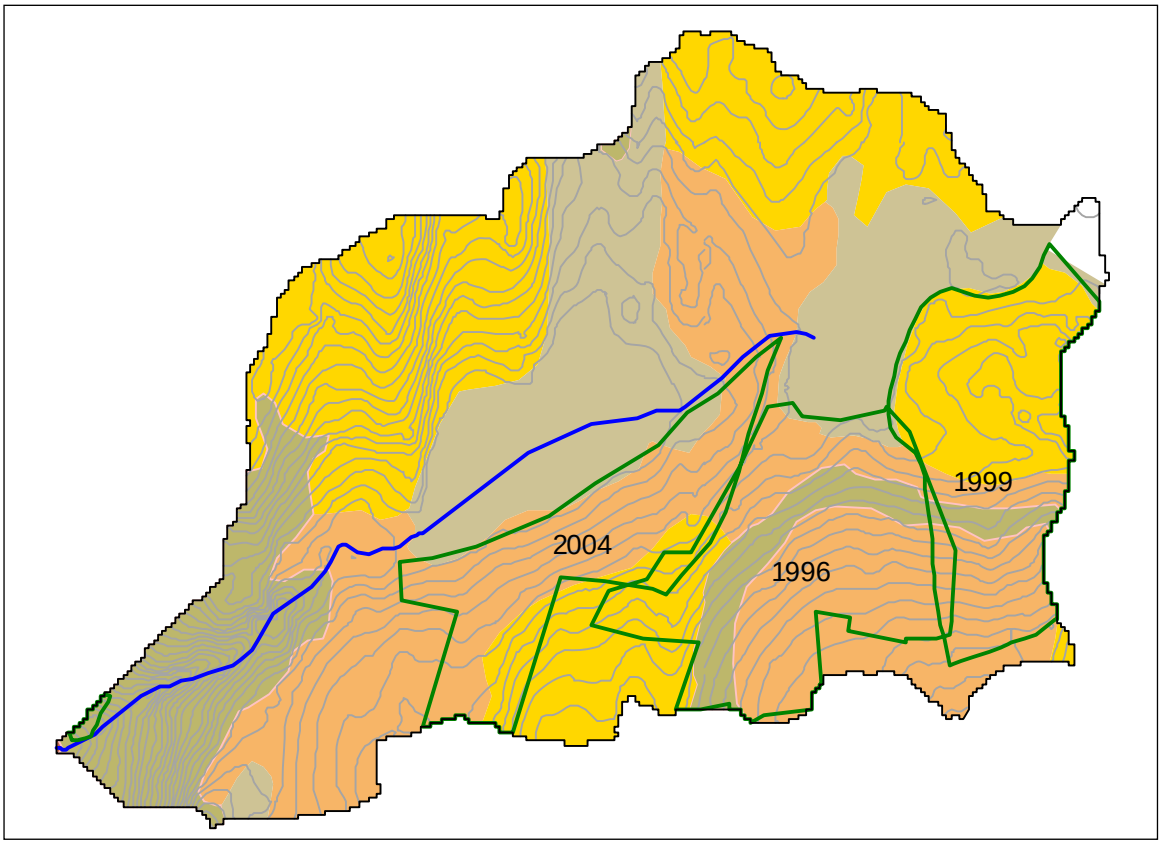
An example of an individual subwatershed map is shown in **Figure 15**. This subwatershed is approximately 638 acres in size, with topography ranging from 531 to 954 feet. The mouth of the drainage is within 1.3 miles of the Shaft 12 intake, and approximately 6.6 miles from the CVA intake. Soil composite types in the subwatershed include: Well-drained thin soils – approximately 33% of subwatershed; Well-drained thick soils – 12%; Moderately-well drained soils – 34%; Poor to very poorly drained soils – 21%. During the past 10 years, 3 logging operations occurred in the subwatershed, covering a total of approximately 210 acres (33% of the subwatershed). However, this work harvested the overstory trees on only 70 acres (11%) of the actual area, and mostly occurred on the moderately or well-drained soils in the subwatershed, so this area remains well below the 25-30% threshold.

5.2.3.2.3 Coordination with OWM Environmental Quality staff

The Environmental Quality (EQ) staff at Quabbin have developed a multi-tiered system for subdividing the watershed for the purpose of organizing the tracking and analysis of management or development activities on private as well as public lands and for monitoring the effects of these activities on water quality. The Quabbin Reservoir watershed is divided by EQ into Districts, Subdistricts, and Stream Compartments. The Stream Compartments correspond most directly with the subwatersheds designated above for the purposes of land management, with some important differences. For example, the shoreline direct drainage areas are merged into Stream Compartments for EQ analysis. For land management purposes and the determination of the 25-30% threshold described above, the only portions of shorelines that can be used in this analysis are those with distinct watersheds. The remainder of the shorelines is primarily drained by subsurface direct flow to the reservoir. Despite this difference in the systems, the EQ and Natural Resources (NR)/Forestry staffs will accumulate information at the EQ Subdistrict level

on at least an annual basis in order to better coordinate responses to mutual concerns. For example, EQ will inform NR/Forestry on the status of private land activities within each subdistrict, and NR/Forestry will provide EQ with a summary, by subdistrict, of past and proposed regeneration harvesting.

Figure 15: Example of a Subwatershed Planning Map Including Topography, Soils, and Previous Harvests



5.2.3.3 Establishment of Forest Management Zones

5.2.3.3.1 Guidance from existing zoning strategies

Once subwatersheds are established, DWSP next establishes three zones within the areas that are to be actively managed. These zones were developed following consideration of other regulatory zoning that affects watershed management practices. DEP, the primary regulator for MA surface water supplies, established three zones to delineate those areas included in 310 CMR 22.00, the Massachusetts Drinking Water Regulations, as Surface Water Supply Protection Zones:

- ***ZONE A:*** represents a) the land area between the surface water source and the upper boundary of the bank; b) the land area within a 400 foot lateral distance from the upper boundary of the bank of a Class A surface water source, as defined in 314 CMR 4.05(3)(a); and c) the land area within a 200 foot lateral distance from the upper boundary of the bank of a tributary or associated surface water body.

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

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

In addition, the Watershed Protection Act established regulatory zones restricting land use and activities within critical areas of the Quabbin Reservoir, Wachusett Reservoir and Ware River watersheds. These zones include two distinct areas, the *Primary Protection Zone*, which is the area 400 feet from the edge of the reservoirs and 200 feet from tributaries and surface waters, in which alterations are prohibited, and the *Secondary Protection Zone,* which is the area between 200 and 400 feet from the banks of tributaries and surface waters, and within which storage, disposal, or use of hazardous materials, the alteration of bordering vegetated wetlands, and dense development are prohibited.

Finally, in 1999, the Division identified a "Pathogen Control Zone" designed to limit the risk of pathogen infection of the water supply at the intakes. At Quabbin, this zone is focused on protecting the Chicopee Valley Aqueduct, and includes the stream and hillside drainages in the Pelham Block and within Quabbin Park that most directly affect the CVA (see **Figure 22,** Section 5.4.4.1.1**).**

5.2.3.3.2 DWSP Forest Management Zones

For the purpose of guiding and limiting forest management activities within Quabbin watershed, DWSP has incorporated principles from the DEP zoning for surface water protection, the Watershed Protection Act, and the Division's Pathogen Control Zones and has developed the following forest management zones (see **Figure 16**):

5.2.3.3.2.1 DWSP Forest Management Zone 1

Zone 1 includes the buffer strips along public roads, the variable width filter strip along streams and water bodies, the DWSP filter strips around all vernal pools, and all other land that is within 200 feet of the bank of tributaries to the Quabbin Reservoir or within 400 feet of the bank of the reservoir itself.

Buffer strips are required by Chapter 132 along publicly maintained ways, but not including forest management roads in public forests, parks or reservations. These buffer strips are 50 feet from the edge of the road unless the road is a designated scenic road, in which case the buffer strip extends 100 feet from the highway. Within these buffer strips, cutting is limited to not more than 50% of the basal area and cuttings in these strips must be separated by at least five years time.

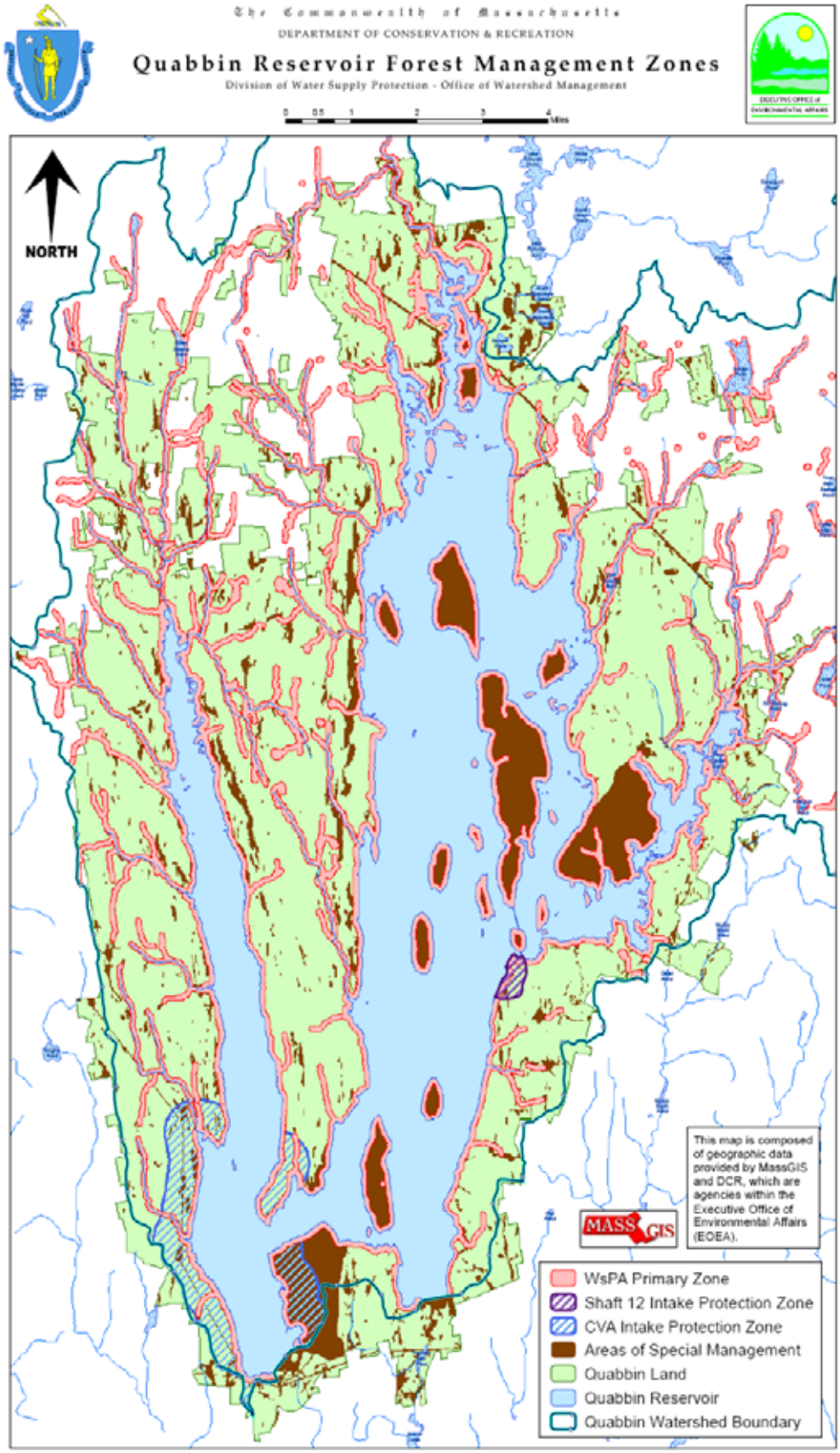
Filter strips are required along all water bodies and certified vernal pools (note that the Division treats all vernal pools as certified, whether or not they have been officially certified). Filter strips are a minimum of 50 feet in all cases, and are of variable width depending on slope along Outstanding Resource Waters (ORW) and their tributaries. Since Quabbin Reservoir is an ORW, all tributaries under DWSP control that also lead into the Reservoir are treated with variable width filter strips.

Vernal pools within DWSP holdings are treated as certified, and therefore subject to the 50 foot minimum filter strip requirement, within which not more than 50% of the basal area may be cut within any five year period. Further details for harvesting around vernal pools are included in **Figure 18 (page 180)**.

In some cases, variable width filter strips may exceed the limits of Zone 1 (for example, where a steep bank mandates a variable width filter strip that is greater than 200 feet wide). Where this is the case, the filter strip boundary determines limitations on harvesting.

In total, Zone 1 covers at least 13,857 acres (this is the acreage in DEP Zone A), or about 24% of the DWSP properties surrounding Quabbin. A smaller area of 7,933 acres is in Zone A and within the manageable portions of the property (i.e., not including islands, steep slopes, Pottapaug Natural Area, etc.; see **Table 41**). Zone 1 represents about 17% of the manageable area.

Figure 16: Quabbin Forest Management Zones



5.2.3.3.2.2 DWSP Forest Management Zone 2

Zone 2, also referred to here as the Intake Protection Zone, is a modified version of the Pathogen Control Zone and the DEP Zone B. For the CVA, this zone includes the area within ½ mile of the portions of the reservoir identified in the Pathogen Control Zone. For the Shaft 12 intake, this Intake Protection Zone is the land that is within a ½ mile radius of the intake, but also no further east than the watershed divide that sheds water either to the west or the east of the baffle dam. The CVA Intake Protection Zone includes 2,435 acres; the Shaft 12 Intake Protection Zone includes 128 acres.

Zone 2, CVA Intake Protection Zone

5.2.3.3.2.3 DWSP Forest Management Zone 3

Zone 3 is the land that is outside Zones 1 and 2 and is hydrologically the most remote zone from the reservoir. This zone covers approximately 36,179 acres or about 62.3% of the DWSP properties surrounding Quabbin. Zone 3 covers about 77.5% of the manageable area.

5.2.3.4 Harvesting Limits Within and Among Zones

As described in section 5.2.3.2, the Division will limit harvesting on a subwatershed basis to not more than 25% of the subwatershed forest cover in any given 10 year period. To reflect both the regulatory limitations and the hydrologic sensitivity of the three zones described in section 5.2.3.3, DWSP will further limit its harvesting activities within each zone.

- In Zone 1, harvesting and wetlands protection regulations require certain limitations on silvicultural practices. In order to address these regulations and the heightened hydrologic sensitivity of these areas, cutting within Zone 1 will be limited to:
  - Single-tree selection or small group or patch selection up to 0.5 acres in size, unless Chapter 132 is more limiting.
  - Within filter and buffer strips, cutting is limited to 50% of the basal area at one time, with a five-year waiting period between harvests, and the residual forest trees must be well-distributed and in good, vigorous health following the harvest.
  - Cutting around vernal pools is described in detail in **Figure 18 (page 180)**.

- In areas of Zone 2, the Intake Protection Zone, that overlap Zone 1, the restrictions on Zone 1 will prevail. In the remainder of Zone 2, harvesting will be limited to single-tree or small group or patch selection, with group/patch size limited to a maximum of one acre.

- Within Zone 3, considered to be hydrologically the most remote zone, harvesting will be in single tree, small group, and patch cutting, with the majority in groups and patches under 2 acres in size, but also including a limited number of larger openings as described below.

With a target of regenerating approximately 400 acres per year, regeneration harvesting will be controlled among all zones. Each year, at least 90% (360+ acres) of the regeneration cutting will be in single tree or small group selection harvests not to exceed 2 acres, and completed within Zone 1 (single tree and small group selection up to 0.5 acre), Zone 2 (single tree and small groups not larger than 1 acre), and Zone 3 (single tree and small groups not larger than 2 acres).

On a limited basis, DWSP will harvest patches greater than 2 acres in size. During the original Forest Stewardship Council certification of Quabbin land management practices by auditors from SmartWood in

1997, the audit report recommended that the Division should include "new management strategies that will maintain and promote biodiversity at the landscape level" (SmartWood, 1997). This recommendation derives from SmartWood observations under Criteria 3.11 for certification, regarding silvicultural prescriptions. SmartWood expressed the concern that, "In many areas on the Quabbin Watershed, the exact same silvicultural prescription is being marked and implemented. The ecological concern is that this will, over time, create a homogenous forest and greatly reduce horizontal diversity." The auditing team recommended that canopy gap sizes should be adjusted to address this concern. While the Division remains committed to the concept of diversifying the forest on the stand level in order to build resistance and resilience, there are hydrologically more remote areas on which achieving landscape-level horizontal diversity through the creation of larger openings is desirable.

In addition, there are occasionally situations in which full removal of the overstory of a stand of trees, even within an overall silvicultural strategy of developing stand level diversity, makes more sense than partial removal. Examples include densely planted artificial stands that were located on wetter sites and were never thinned. Due to the very weak form of the individual trees in these stands, partial cutting frequently leads to wind throw of the remaining stand. There may also be situations in which disease has entered a stand and is threatening to spread farther. In these situations it is sometimes desirable to cut out the entire diseased portion of the stand to prevent further spread and/or to more rapidly regenerate the stand to a more resistant mix of species. Finally, there are areas within the watershed forest that are hydrologically remote from the reservoir and on which it would be desirable to open a large area in order to produce early successional habitat for the benefit of certain wildlife species. Larger openings focus the harvesting on a smaller percentage of the management unit and can thereby reduce the percent of the area that is traveled by the harvesting equipment. Furthermore, these larger areas of regeneration do not require additional tending to release established regeneration. As the actual transport of the harvested trees presents a greater challenge to protecting water quality than the cutting of those trees, the reduced transport traffic may be an important benefit of larger openings in some areas.

In response to the recommendations for maintaining structural diversity at the landscape level, and to allow some flexibility for full overstory removals, each year up to 10% (40 acres) of the regeneration cutting will be in patches greater than 2 acres in size. These larger openings will be completed within Zone 3 only.

In addition to being at least 400 feet from the bank of the reservoir and at least 200 feet from the bank of any tributary to the reservoir, openings greater than 5 acres will *not* take place within the Pathogen Control Zone (see **Figure 22, page 219)**, will be on land that is hydrologically remote from the CVA and Shaft 12, and will be justified on the basis of meeting secondary objectives for biological diversity (early successional habitat creation) or to address a silvicultural concern. These larger openings must also be proposed within reasonable constraints on slope, soil and forest types, and will have additional public notice and review before implementation. The specifics of these proposed larger openings will be reviewed internally each year, as a component of the annual internal review of proposed harvesting (see Section 5.2.7).

By GIS analysis, the breakdown of DWSP properties by zones within the manageable portions of the Quabbin Reservoir watershed is shown in **Table 41.**

Table 41: Acres by Management Zone

Area	Acres	% of Total	% of Manageable
Total Quabbin DWSP holdings	58,412	100.0	NA
Areas with Special Management Restrictions			
Islands	3,674		
Steep slopes	1,712		
Wetlands	2,272		
Pottapaug Natural Area	1,183		
Quabbin Park (western portions)	1,058		
Others (cultural, rare species habitats, etc.)	1,837		
Total Areas with Special Management Restrictions	11,737	20.1	0.0
Manageable Area			
Manageable area in Zone 1	7,933	13.6	17.0
Zone 2, the Intake Protection Zones	2,563	4.4	5.5
(Zone 1 areas *within* Zone 2)	(734)	-	-
Manageable area in Zone 3	36,179	61.9	77.5
Total Manageable Area	46,675	79.9	100.0

5.2.3.5 Protection Provided for Water and Wetland Resources by Zones

Water and wetlands are the most important resources on drinking water supply watersheds. The zoning strategy outlined in Section 5.2.3.3 is designed to provide exceptional protection for these resources on the Quabbin Reservoir watershed. This protection is provided by overlapping policies, and in summary provides the following:

1. Tree harvests will not exceed 25% of any given subwatershed in any given 10 year period in order to protect against undesirable increases in water yield and associated increases in sediment and nutrient transport.

2. A minimum fifty foot filter strip will be maintained along all water bodies and vernal pools, as provided by Chapter 132, in which harvesting is limited to 50% of the basal area. As Quabbin Reservoir is an Outstanding Resource Water, this filter strip is of variable width, increasing with slope along the edge of the reservoir and all tributaries to the reservoir.

3. All stream crossings within 1,000 feet of the reservoir will use a portable bridge, as required by Chapter 132. A "stream" for these purposes is defined as "a body of running water, including brooks and creeks, which moves in a defined channel due to a hydraulic gradient, and which flows within, into, or out of an area subject to protection under the Wetlands Protection Act…Such a body of running water, which does not flow throughout the year (intermittent) is a stream except for the portion up-gradient from all bogs, swamps, wet meadows, and marshes." The Division furthers this protection by committing to cross all flowing water, regardless of its location or permanence, on a portable bridge so that even intermittent streams that are up gradient of wetlands will be crossed using a bridge if they are flowing or are likely to flow during the time that the work is being conducted.

4. Cutting practices and opening sizes will be restricted in areas of the Division's Zone 1 that are within 400 feet of the edge of the bank of the reservoir and 200 feet of the edge of the bank of all tributaries to the Reservoir. The minimum expression of this zone is shown in **Figure 14**. The Division recognizes that the mapping data used to define the area covered by DEP Zone A (and therefore, the Division's Zone 1) has missed some significant tributaries that flow to the reservoir.

This map, and its application in the field, will be subject to interpretation. A significant tributary that is not shown on the map will still receive the protection provided by Zone 1. An intermittent stream that is not shown will be protected according to Chapter 132 and the Division policy regarding stream crossings.

5.2.3.6 Species Composition Objectives

5.2.3.6.1 Diversity of Species Composition

The current species composition for the Quabbin forest is described in Section 2.4.2. The dominant species in the overstory of this forest are white pine and red oak, and the top ten species are shown in **Table 42**. There is no current plan to deliberately alter this landscape level species composition, with the exception of red pine, which occurs on the watershed due to planting rather than through natural regeneration and is frequently susceptible to the root rotting fungus *Heterobasidion annosum* (formerly called *Fomes annosus*). The Division has worked to replace red pine plantations with diverse natural regeneration of native species. As a result, the overstory stocking of red pine declined from 7.3% of the total stocking in 1990 to 2.8% of the total in 2000.

While there is no plan to deliberately alter the composition of the overstory (other than to reduce planted red pine), a number of changes in overstory composition are occurring naturally that will influence future composition. The Hemlock Woolly Adelgid, discussed in detail in section 5.2.4.1, arrived on the watershed within the past decade and is reducing the overall stocking of this species at a relatively rapid rate. The adelgid affects all ages of hemlock, from mature overstory trees to the youngest regeneration. Among other species impacts, white ash remains in decline as a result of a suite of pests. As the Quabbin forest has been maturing without catastrophic disturbance for many decades, the early successional species such as grey birch continue to decline.

Table 42: Top Ten Quabbin Overstory Species in 2000

Species	% of 2000 Stocking
White pine	28.2%
Red oak	19.6%
Red maple	13.3%
Hemlock	8.9%
Black oak	6.8%
Black birch	4.9%
White oak	3.8%
White ash	3.5%
Red pine	2.8%
Sugar maple	1.8%

In the most recent regeneration surveys for the Quabbin watershed, white pine dominated the understory trees species, with red maple and black birch also well represented across the watershed. The oaks were less abundant and are notoriously more challenging to regenerate successfully (it is well-established that the dominance of oak in the current overstory forest relates in part to the intensity of precedent land use disturbances, including fires and clearcutting, as well as lower deer pressures at the initiation of these stands). While the oaks are well-represented in regenerating stands, they are not as strong in the understory as they are in the overstory at Quabbin, a trend that is likely to continue due to a variety of difficulties in regenerating these species. Hemlock regenerates well, but the regeneration is as susceptible to the Hemlock Woolly Adelgid as the overstory. Protracted deer browsing impacts have resulted in a variety of challenges to replacing the current overstory. White pine and black birch each persisted in

areas with mildly elevated deer numbers and on large segments of the watershed they are likely to dominate the species composition there at least through the current rotation. This condition may also have consequences for water yield, due to the higher annual potential evapotranspiration of the conifers versus the deciduous hardwoods.

Allowing more options for group/patch size in zone 3 should enhance species diversity due to the greater variety of microclimate and shade conditions that can be produced with a greater variety of opening sizes. Shadows from overstory trees adjacent to forest openings can be very long for much of the day during the growing season. Therefore species requiring full sun for much of the day to compete well should benefit from larger openings and/or from orienting irregular-shaped openings to reduce shading (e.g., north/south rather than east/west). The number of native species in this region that compete best in full sun is greater than the number of species that compete best in partial sun.

In the past decade, a moose population has established itself at Quabbin and the effects of this population on species composition are locally apparent. In studies from areas other than Quabbin, moose have shown strong preference for red oak, red maple, hemlock, striped maple, black and yellow birch, ash, sugar maple, poplar, blackberry, and witch hazel. Once again, white pine is not preferred by this browser, so that as the moose population rises, white pine regeneration is likely to benefit further.

5.2.3.6.2 Species/Site Suitability

Species/site suitability incorporates the many environmental variables that determine how individual tree species regenerate and prosper, both by themselves and in the presence of other species. The science of *silvics* concerns itself with the environmental requirements of species. Most native trees in the Quabbin forest grow and compete on a wide range of sites, but to varying degrees of success. There are specific site conditions where each species grows best and sometimes different conditions in which that species will compete best against other species. For instance, while the most vigorous growth by white pine occurs on mesic, well-watered sites (often toward the base of hills), hardwoods also grow well on these sites and may out-compete white pine in the early stages. On drier, uphill sites, white pine grows moderately well and can out-compete the more moisture dependent hardwoods.

Quabbin soils are predominantly acidic in nature due to underlying granitic rock. Acidic soils support our most common trees: white pine, red and black oak, hemlock, and red maple. Trees that require more alkaline soils, such as sugar maple or basswood, are present but not common to this area. Soil moisture availability and soil drainage are also important factors in site suitability. The pines do well on well-drained soils, where these evergreens can capture moisture throughout much of the growing season with an extensive root system. Optimal conditions for white pine are well-drained sandy loam soils in river valleys with available moisture, three to four feet below the surface. The oaks do well on soils that are moderately well-drained and have moisture available for much of the growing season. Optimal conditions for oak occur on terraces at the base of steep slopes, where moisture and nutrients accumulate.

Site/species associations on the Quabbin landscape have been influenced, sometimes dramatically, by human land-use practices. The use of fire to clear land as well as fires started accidentally in the remains of past harvesting practices has favored the establishment of oak simply because it is among the species most capable of recovering (through vigorous sprouting) following fire. Tree planting that occurred in the 1930s and 1940s often placed non-native conifer species on sites where they would grow well (mesic agricultural fields), but where they also were more susceptible to such problems as *Heterobasidion annosum* (formerly called *Fomes annosus*) root-rot. Grazing practices left behind species that were not preferred by the grazing animals, but that might not be the native species best able to grow vigorously on these sites. There are vast acreages throughout New England of former grasslands into which white pine was able to establish seed and grow, but under conditions that favored the white pine weevil. As a result, the pine growing on these sites tends to carry a weak form caused by repeated weevil-kill of its terminal shoot.

It is an objective of Quabbin forest management to grow a vigorous, low-maintenance forest. This objective will be met more successfully as the species combinations growing on any given site are assessed for their suitability and, if necessary, moved toward more vigorous combinations. For instance, while DWSP has aggressively converted off-site red pine plantations to mixed combinations of native species, some of this type of conversion remains to be completed. Likewise, poorly formed white pine growing on old field sites will continue to be converted to mixed species combinations that are likely to persist longer in the face of both chronic and catastrophic stressors.

5.2.3.6.3 Water Use by Species

It is a goal of this management plan to maintain current water yields (see Water Yield Goals, Section 4.1.2). As the annual potential evapotranspiration rates are significantly higher for evergreen/conifer types than for hardwood/deciduous types, maintaining the current balance of these types will be important in meeting the goal to maintain current water yields. In spite of the conditions that favor an increased dominance of white pine in the regeneration of the next forest, it will be an objective of the Division to retain the current balance of evergreen overstory types versus deciduous types. At the present time, softwoods occupy 21% of the Quabbin forest, hardwoods occupy 47%, and mixed types occupy 25%. While white pine types may increase at the expense of some of the more difficult to reproduce oak types, this will be balanced by the conversion of red pine and hemlock types to mixed or hardwood composition.

5.2.3.6.4 Nutrient Control

Research indicates some variability among eastern US forest species in their ability to control nitrogen losses (Lovett, et al., 2002; Lewis and Likens, 2000; Christ et al., 2002). The carbon to nitrogen (C:N) ratio in and at the surface of the soil is important among the causes of these differences; a high ratio results in a high demand for N by soil microbes, so that nitrification rates are lower and the export of N off the site is less likely when the C:N ratio is high. C:N ratios relate predictably to overstory tree species composition in areas of the eastern U.S. For instance, C:N ratios in the Catskills in New York were higher under red oak and red maple stands than under sugar maple stands, and N export was higher from sugar maple stands than from red oak or red maple stands (Lovett, et al., 2002).

Studies in Eastern hemlock stands have indicated similar relationships. Hemlock produces an acidic duff layer as well as a cool, dark understory that in combination result in slow decomposition rates and a high C:N ratio. This high C:N ratio also supports low nitrification rates and low nitrate or cation export (Yorks, et al., 2000; Finzi, et al., 1998). Where mortality occurs in hemlock stands, temperature, decomposition, and nitrification rates increase; nitrification rates in gaps in the hemlock forest can be as high as twice those within the undisturbed hemlock forest (Mladenoff 1987). The conversion of hemlock to deciduous replacement types can result in an increase in pH and in mineralization/nitrification rates, as well as a long-term decrease in stored cations leached by nitrate and other anions. These changes are of particular concern where hemlock is growing adjacent to streams due to the increased possibility of moving nutrients into the stream water (Yorks, et al., 2000). Research has further shown that *Betula lenta* (black birch), which commonly regenerates beneath damaged hemlock stands, is capable of capitalizing on nitrate availability more efficiently than some other species (Crabtree and Bazzaz, 1993).

The Division recognizes that changes in species composition are brought about by a wide range of variables, and thus has not set rigid species objectives. The concern for long-term nutrient dynamics will nevertheless be a consideration in silvicultural practices that are likely to alter forest type.

5.2.3.6.5 Economic Value

Economic value does not directly influence a tree's value for water supply protection. However, the options for silvicultural treatment of these forests may be enhanced to the extent that the commercially more valuable species can be regenerated and grown. The commercial value of a particular species is

subject to the variations in consumer demand, although some species have remained relatively high in value for long periods of time.

White pine is a versatile species that is easy to use in a wide variety of commercial applications, is relatively easy to reproduce and grow, and can be produced in higher volumes on a given acreage than most other species. Red and white oaks are more difficult to regenerate, but have maintained a high market value until recently, and even recent declines leave the oaks still among the top species for value per board foot. Red maple has traditionally been a relatively low value species, sold primarily for fuelwood or pallet stock, but recent consumer preference for the light-colored hardwoods has significantly increased the value of sugar maple and even the better quality red maple. Most of the region's birches (paper, yellow, black) have traditionally sold to fuelwood or hardwood pulp markets, although the very best birches can be sold to the veneer market, where the clear-faced logs are peeled to make birch-veneered cabinets. Black birch can command high prices when individual stems reach veneer log dimensions without degradation. The frequent occurrence, however, of the *Nectria* fungal canker results in damage to the tree that prevents it from reaching full potential value.

Hemlock has grown well in the Quabbin forest, but has not generally commanded high prices, although the demand for hemlock as pulp increased significantly during the past decade. The Hemlock Woolly Adelgid has increased the volumes of hemlock sent to market, which can further depress market value as landowners rush to salvage value from threatened stands.

5.2.4 Implementation of the Forest Management Approach

Zones 1, 2 and 3 have been identified and mapped, as well as most subwatersheds. As mentioned above, there are forest management limitations imposed by the zoning scheme to help protect water quality but these zones do not provide specific harvesting locations. Our goal is to regenerate 10% of the managed forest over the next 10 years, distributed throughout all three management zones. The decision on which 10% will be regenerated and which 90% will not be regenerated will be based primarily on stand conditions For administrative purposes, Division holdings on the Quabbin watershed have been divided into five management blocks. These blocks will be divided into 20 -50 working units per management block. The management units in north Quabbin will use existing compartments as working units (there are currently 93 compartments averaging 580 acres in size at Quabbin). The management units in south Quabbin will be divided into 20 to 50 working units, delineated by streams, roads, stone walls or other permanent features. Each management block is about 12,000 acres and is treated as a separate sustainable unit. . Within the next 10 years, the working units/compartments within each block will be divided into stands and inventory data will be collected on these stands. Each working unit/compartment and all stands within those working units/compartments will be visited on ten-year intervals. Stand examinations will be conducted on these visits and the data collected will be used to prioritize stands needing silvicultural treatment. These data will be entered into a database to create long term profiles of stand and forest level change to augment the CFI system. Data collected for each stand will include:

- relative stand density (basal area - high, medium, low for stands of this type)
- stand height (20' ht classes)
- forest type
- stand age (20 yr age classes)
- regeneration type and adequacy
- relative stand condition (vigor/quality - high, medium, low)
- special features (unique habitats, vernal pools, significant forest and wildlife features)

Silvicultural activities will be dispersed across the watershed to enhance diversity and aesthetic amenities by following a sequential pattern. Working units will be numbered one through n (n=number of units for this management unit). Each year about 10% of the working units/ compartment will be examined, starting the first year with compartments/ units 1,11,21,31,41, etc., with 2,12,22,32,42, etc., examined the second year, and so on until the entire forest has been covered. This planned pattern may be disrupted by the need to address pest or weather disturbances, but will generally dictate the areas to be treated.

Priorities for treatment will be set using stand examinations in each year's working units/compartments. To achieve a diverse age structure, about 1% will be cut in each zone each year. This may vary from year to year but will equal 10% after ten years.. Over time, this cutting regime will begin to balance the age structure of the forest in these areas, adding resistance and resilience to the forest cover.

Stands within zones 1, 2 or 3 will be prioritized for silvicultural work as follows:

- lack of species and or structural diversity (i.e., plantations or native single-species stands)
- high risk of stand not surviving another 10 years (e.g., insect and disease problems)
- low vigor/low quality trees occupying the growing space
- undesirable non-native species
- stands with advance regeneration in place requiring release
- stands with rapidly declining overstory trees

While approximately 12,000 acres will be designated as unmanaged areas within the Division's holdings surrounding Quabbin Reservoir, the remaining 46,000 acres will be actively managed to maintain resistance and resilience through deliberate improvements in age and species diversity within any given subwatershed. The silvicultural disturbance of these managed areas will reflect the average rate of natural disturbance in these forests, which ranges from approximately 0.5% to approximately 2.0% per year (Attiwill, 1994), or approximately 1.0% per year on average. To meet this objective, approximately 1% or approximately 400-450 acres of the managed forest will be regenerated annually, on average, during the next 10 years.

5.2.4.1 Silvicultural Practices

Forest management activities during the period covered by this management plan continue to emphasize the development of multi-aged or uneven-aged conditions on the majority of the managed area of approximately 46,000 acres. Uneven-aged stands are defined as those that contain at least three distinct age classes, differing in total height and age (Smith, et al., 1997), and managed on cutting cycles that enable established regeneration to be released sufficiently to be free to grow as new age classes. Uneven-aged silviculture, focused primarily on small-group selection, tends to favor shade-tolerant and mid-tolerant species. In order to regenerate the less tolerant species, and to provide a more varied forest structure across the landscape, the plan also accommodates patch cutting, in which opening size and shape provide conditions in some portion of the opening that are outside the influence of the mature trees on the edge of the openings (generally when the opening is at least twice as wide as the height of the tallest surrounding trees, although this will vary with slope and aspect). The combination of methods that includes patch cuttings supports a range of species and ages that may not strictly follow the definition of uneven-aged structure, and is referred to instead as multi-aged structure. While sustainability is often measured by the balance between growth and harvest, the silvicultural objective for the management of the watershed protection forest is primarily driven by the need to provide long-term protection for water quality, rather than the need to produce an optimized, consistent flow of wood products.

2-year post harvest multi-aged structure developed via small group selection on Prescott Peninsula

5.2.4.1.1 Regeneration methods

The proposed regeneration silviculture for this ten-year management period at Quabbin will consist primarily of small group and patch selection cutting. Regeneration establishment may also be encouraged through limited "enrichment" planting if necessary. So long as herbivore pressure and competing native or exotic vegetation are kept under control, regeneration establishment is generally very successful in the Quabbin forest. Seed sources are diverse and frequently prolific, and regeneration monitoring shows high numbers of seedlings established on the forest floor with few exceptions. In the few cases where this natural regeneration has been impaired, a limited amount of

Recently harvested small group selection and patch cuts, New Salem block

planting may occur to enhance the diversity and/or the density of the seedling pool (enrichment planting during 1995-2005 is summarized in **Table 44**).

The majority of the harvesting that will take place at Quabbin over the next decade will be made to release regeneration that has become established in the understory or will become established within 5 years , thus developing new age classes capable of persisting to mature overstory trees. Advance regeneration will not be required on all lots due to the relatively small average opening sizes proposed in this plan. Seed sources are abundant in most of the forest and the proposed openings provide environmental conditions that allow a diversity of regeneration to become established in a short time period on most sites.

The overall DWSP silvicultural objective remains focused on the development of a multi-aged forest for water supply protection, with age diversity ranging from multi-aged or uneven-aged conditions in stands where small group selection cutting is the chosen silvicultural method, to primarily even-aged conditions on the limited number of small stands that are regenerated with patch cuts greater than two acres. The general distinction between a "small group" and a "patch" revolves around the influence of edge trees over regeneration within the opening. Where the shape and size of the opening retain the influence of the surrounding trees, it is considered a small group. Where portions of the opening are beyond the influence of the surrounding trees, it is considered a patch. Small groups may be as small as the area released by cutting a single large tree, or as large as two acres if the cut area is relatively narrow in shape.

In timber sales where the average size group is under ½ acre, all groups will be estimated to the nearest 1/10 acre and all groups over 1/10 acre will be measured using GPS units. In timber sales where the average opening size is ½ acre or more all groups/patches will be estimated to the nearest ¼ acre and all groups over ¼ acre will be measured using a GPS unit. Residual basal areas under 10sqft will be ignored when calculating regeneration acres. In areas that lack regeneration, shelterwood and seed tree type cutting will be an option provided the seed cuts are not larger than the allowed opening size for the zone in which the cutting takes place.

Table 44: Enrichment Planting of Tree Seedlings, 1995 - 2005

Year	Red Oak	White Pine	Norway Spruce	Red Pine	Sugar Maple	White Ash	White Oak	Hemlock	Others	Total
1995	5,900	20,000	10,000	0	2,600	6,600	0	0	0	**45,100**
1996	10,000	33,000	0	3,000	0	0	0	2,000	0	**48,000**
1997	14,000	10,000	0	0	2,000	0	1,500	0	0	**27,500**
1998	13,000	9,000	0	0	2,000	0	1,000	0	0	**25,000**
1999	21,000	0	7,500	0	0	0	1,500	0	0	**30,000**
2000	20,000	23,000	0	0	0	0	0	0	0	**43,000**
2001	300	4,000	2,000	2,000	280	0	0	0	500	**9,080**
2002	6,000	2,000	2,000	2,000	0	0	0	0	300	**12,300**
2003	11,500	5,100	4,000	4,000	0	0	0	0	0	**24,600**
2004	5,000	0	0	6,000	0	0	0	0	0	**11,000**
2005	NO SEEDLINGS PLANTED									**0**
Total	**106,700**	**106,100**	**25,500**	**17,000**	**6,880**	**6,600**	**4,000**	**2,000**	**800**	**275,580**

5.2.4.1.2 Post Harvest Monitoring of Regeneration Cuttings

Many things influence the outcome of regeneration cutting. Site conditions such as shade, soils, aspect, seed sources, forest floor disturbance, or advance regeneration can have some impact on the desired regeneration. Herbivores such as moose, deer, and beaver as well as insects, diseases, weather conditions, and fire can also have very serious impacts on regeneration. Because many of the things that can

influence the outcome of regeneration cutting are constantly changing, it is often difficult to predict in advance what their impact on regeneration will be several years after the harvest. In order to keep up with and adjust to these potential effects on regeneration success, all timber sales involving regeneration cutting will be inventoried 2 -5 years after harvesting. At this time our greatest concern is the impact of moose on regeneration; methods are under development to quantify this impact.

5.2.4.1.3 Intermediate Cuttings

Intermediate cuttings are performed on stands prior to maturity. They are designated as "thinnings" when the objective is to remove trees of low vigor thereby decreasing competition within the stand and increasing the vigor and growth rate of the remaining trees. "Improvement" operations are designed to adjust the species and quality composition of stand. In fact, virtually all intermediate cuttings are a combination of both thinning and improvement. The defining characteristic of all intermediate operations is that there is no intention regarding the establishment or encouragement of regeneration. However, because the age structure at Quabbin is predominately older, maturing stands, it is difficult to avoid a regeneration response after an intermediate cut. If the regeneration that becomes established after an intermediate cut is not released within 10 years, intermediate thinnings will favor the more shade tolerant regeneration on many sites. In order to reduce the potential future impacts on species diversity (predominately shade tolerant species) we have reduced the amount of this type of cutting at Quabbin. As the age structure of the Quabbin forest changes to include more trees in the 20 to 60 year old age classes, the amount of intermediate treatment may increase.

Due to the relative scarcity of purely pole-sized stands on Division property at Quabbin, intermediate cuttings are rarely performed as the sole objective. Most intermediate operations are performed simultaneously with regeneration cuts, especially in stands that are being treated for the first time without the benefit of prior or recent management or those that have not been treated for many years. During the next ten years, intermediate cuttings may occur on up to 200 acres per year.

5.2.4.1.4 Riparian Zone Management

The most common riparian zone management strategy land managers take in a variety of plans and Conservation Management Practices is simply to leave these areas alone. In fact, this strategy has the force of law in many states, as a component of wetland protection or timber harvesting regulations. MGL Ch. 131 (Wetlands Protection Act) and Ch. 132 (Forest Cutting Practices Act) both contain language that restricts activities within riparian zones. The assumption behind these regulations is that manipulations of these zones will degrade the critical buffering capacity of these areas and may result in soil disturbances that are more likely to result in sediment transport into streams. Studies show, however, that it is the activity associated with removing trees that is associated with these impacts, not the act of cutting them. DWSP recognizes these zones as the final and therefore most critical opportunity to slow or capture nutrients and sediments released by the variety of natural and human-caused events on the watersheds,

Lower reaches of Underhill Brook

and therefore does not categorically exclude them from management.

The preferred vegetative structure of riparian zones is an actively growing, diverse, self-perpetuating, and disturbance-resistance forest cover. Carefully planned and implemented human intervention may be the best method to maintain this forest structure throughout the variety of disturbances that impact all New England forests. To some degree, when these forests are within the bottom of stream and river valleys, they may be sheltered from winds. However, as riparian forests mature, and especially when they are in the path of destructive storms, they become vulnerable to sudden and dramatic change. When wind-throw or flooding occurs, it is of great concern to watershed managers because it can result in substantial amounts of soil and nutrient transport. Additional concerns include sudden changes in stream temperatures due to loss of forest cover and heavy accumulations of woody debris and sediments when trees fall directly into streams or the streams are dammed.

The most important source of resistance and resilience to build into the riparian forest is the establishment of regeneration. This regeneration serves to anchor soils following disturbances, resists damage from many disturbances (due to size and density), and shortens recovery times for reestablishing riparian forest following most disturbances. Riparian forest that is simply left alone may establish sufficient regeneration as the overstory begins to age and decline in vigor. However, where full crown closure is maintained for long periods of time (especially in hemlock stands), understory development will be limited by low understory light and thus there will be delays in recovery following major disturbances. Through carefully implemented manipulations of the overstory and understory, DCR managers intend to systematically "condition" certain vulnerable riparian forest to be better able to maintain their critical buffering functions throughout significant disturbances.

Directional felling of small groups and individual trees, without removal, may be done to bring light to the understory where soft soils prevent equipment of any size. Trees will be felled perpendicular to the prevailing slope and cut into sections so that trunk comes in contact with the ground to enhance the debris and sediment trapping capabilities of the riparian zone. Felling will not be done into streams. It has been demonstrated that the natural fall due to individual tree mortality (as opposed to catastrophic events) will add sufficient material in streams to create beneficial debris dams.

5.2.4.2 Silviculture by Forest Type

The principal forest types on Quabbin are described below, with a brief description of silvicultural approaches applicable to each type within the context of watershed management. These types may occur as pure stands, or more often as mixed forest with either gradual or sharp type changes related to soil types, aspect and elevation, and past land use history. **Table 18** in section 2.4.2.1 above provides details on all types and subtypes from the most recent aerial photo and field interpretation.

1) Oak Types

Red, black, scarlet, white, and chestnut oak comprise the five major species in this type, with red oak generally the most vigorous, dominant component. The type grows best on the more fertile, moist, moderately well-drained sites. Because of its superior vigor, red oak will be favored where moisture is sufficient to support its growth. While Quabbin is host to some of the largest contiguous oak stands in the Northeast, it is important to recognize that these stands were established through dramatic clear-cutting and burning, landuse practices of the past that were tolerated better by oaks than by most other competing species. Regenerating red oak through more conventional silviculture has been difficult, especially as these are desired species for browsing ungulates (deer, moose). It is likely, therefore, that the multi-aged silviculture proposed by this plan will ultimately result in the replacement of these oak stands with a wider diversity of species. While this replacement may compromise other values of these contiguous

stands, such as hard mast (acorn) production, it supports the Division goal of increasing species diversity to improve stand resilience.

Scarlet and black oaks are plentiful on some well-drained upland sites (where lack of moisture limits red oak) but are generally of poor vigor. Gypsy moth infestations in the past have been most severe on these drier sites. Consequently, efforts have been made to increase the component of other species on these uplands, e.g. by salvaging dying oaks and underplanting with white pine in the resulting openings. White pine survives and grows well on these sites and the majority of these black and scarlet oak stands will eventually be converted to mixed stands of oak, white pine, and other species.

White oak, like black and scarlet oak, is also found growing on dry upland sites. However, it exhibits its best growth on moister soils. The acorn of the white oak is less acidic than that of the other, more abundant oak species, and consequently more valuable to wildlife. On the Quabbin watershed, white oak was a primary host to the gypsy moth and, due to physiological differences, suffered more severe mortality than the red oaks. White oak that is surviving and growing vigorously will receive preferential treatment in order to maintain the species as a component on the watershed.

Chestnut oak is primarily found growing on the poorest of upland sites on southern and eastern exposures in shallow soils, especially inside of Route 202. North of Route 202 in the West Branch of the Swift River, chestnut oak was commonly found growing with red and white oak. However, gypsy moth infestations of the early 1980s eliminated most of the chestnut oaks from these stands. Regeneration of chestnut oak has been successful where deer pressure has been reduced by hunting. Because this species occurs in relatively few sections of the watershed, it is desirable to maintain it where possible as the major component of a mixed stand as opposed to aggressively converting these sites to white pine.

2) White Pine Types

White pine is among the fastest growing species in the region and responds well to management. It is found most often on dry, sandy sites where hardwoods do not grow well or in abandoned pastures and fields where its heavier seed was capable of penetrating the thick grasses more successfully than hardwood seed (Spurr and Barnes 1980:444). White pine grows most vigorously on moist sandy and silty loams, but it is difficult to establish on these sites because of hardwood competition. Where deer browsing levels have been moderate, there are moist sites where white pine has become established on moist sites due to preferential browsing on hardwoods. These areas will eventually support a more mixed composition, but will tend toward white pine for the next generation.

Most of Quabbin's white pine stands are 65 to 100 years old, the result of natural seeding in old, abandoned pastures and fields, vestiges of stands damaged during the 1938 hurricane, and remnants left over from silvicultural operations prior to DCR ownership. White pine that becomes established in low densities in abandoned pastures is often exposed to repeated white pine weevil infestation. The resulting multiple-leader crown is often more susceptible to wind and ice damage and subsequent fungal invasion than high-density, forest-grown white pine.. Where these occur as isolated trees, they do not constitute a risk to watershed cover maintenance. However, where they comprise the majority of a stand, their gradual removal and replacement with understory trees that will develop a stronger form is desirable.

Some of the Quabbin white pine component is within plantations established in the 1930s and 1940s. Many of these plantations were planted as a mix of red and white pine. The sites chosen were often moist, rich agricultural sites, where red pine grew much more vigorously than white pine. In addition, these moist sites correlate with high infestations of the white pine weevil. As a result, much of the white pine that has survived in plantations is suppressed beneath the red pine, and shows signs of repeated

weeviling. Intermediate cuts in the few remaining mixed pine plantations will continue to preferentially remove the white pine.

3) Red Pine Type

Red pine is an uncommon native species in this area, but was successfully established, in conjunction with planted white pine, on approximately 2,750 acres on the Quabbin watershed during the 1930s and 1940s. Red pine is capable of growing well on a variety of sites, but is most stable on moderately well-drained, sandy loams, where root depth is less limited. On the more moist and fertile sites, red pine has grown to a total height of 90 feet and a diameter at breast height in excess of 24" within 50 years from planting. However, it is on these same sites that red pine has exhibited susceptibility to root rot disease (*Heterobasidion annosum*, formerly called *Fomes annosus)* and to wind throw. For watershed purposes, it has therefore been an objective for more than a decade to convert these sites to a more reliably stable cover of mixed native hardwoods. This conversion was aggressively promoted during the previous management period, and many of these susceptible stands have been successfully converted. Where root rot diseases have killed more than scattered trees, sanitation clearings will continue to be conducted in remaining moist-site red pine plantations, both to halt the spread of the disease (which passes from tree to tree through root grafting) and to hasten the conversion to site-suited species.

4) Birch/Red Maple Type

Black and paper birch, as well as red maple, will occur as pioneer species on many sites, but this overstory type is generally found growing only on moist sites, where red maple is usually the dominant species. While it tolerates these sites better than most species in the establishment phase, maturing red maple is quite susceptible to heart rot where soil drainage is slow. Generally, the black and white birches that establish successfully in these areas do not thrive beyond about forty years of age. Black or sweet birch is particularly susceptible to *Nectria* canker, and paper birch in these areas may develop red heart, a fungal complex. Both the stems and branches of the birches are damaged easily by ice and heavy snows.

In some cases, birches dominate the overstory because they were a less preferred deer browse in early stages of succession, or were able to outgrow livestock grazing on pasture sites. The same browsing/grazing pressure apparently prevented later successional stage components, such as oaks, ashes, sugar maple, and hemlock, from replacing the pioneers. Where there are scattered stems or small groups of more long-lived species, intermediate cuts will favor their growth and development as seed sources. Where long-lived species are missing, regeneration cuts will reestablish more comprehensive stand development.

5) Hemlock Type

Hemlock grows most often in cool moist areas along brooks and streams and on north-facing slopes, but is also found on a wide variety of other sites. Hemlock stands are generally the best winter deer cover on the watershed and have been heavily browsed. As a result, hemlock regeneration has been extremely limited across the Quabbin Reservation. While gypsy moth and the hemlock looper have attacked individual trees or stands for many decades, their impact pales compared to the devastating impact of the hemlock woolly adelgid. See section 5.2.4.1 for much greater detail on this pest and the agency's forest management response.

Due to these pressures on the species, the majority of silviculture within the type during this decade will be salvage operations and scattered intermediate cutting to maintain vigor and seed-producing capabilities. However, where diversification of vertical structure within hemlock stands is desirable,

regeneration cuts may be conducted within the constraints of the current hemlock woolly adelgid management policy.

6) Spruce Type

The majority of the spruce trees growing at Quabbin were planted in the late 1930s and early 1940s. Norway, red, and white spruce were planted. While some of the Norway spruce plantations have grown very well (in particular, on Prescott Peninsula), the red and white spruce generally did poorly. Approximately 500 acres of spruce plantations survived establishment. Limited silviculture was conducted in these stands during the past decade, taking advantage of the ability of mechanized harvesting equipment to fell and process the typically limby stems within these dense, generally unthinned plantations. Markets have been fairly strong for this species in recent years. These improved opportunities will be utilized to create additional forest layers as needed in these uniform stands. Spruce regeneration has been most successful in more open conditions and efforts will be made to gradually enlarge existing openings and create new openings to perpetuate this unusual component of the forest.

There is evidence in the literature that some of the spruces are among the best choices of species for wind tolerance. Spruce wood is generally quite strong relative to other conifers, and its stem tapers very slowly, increasing resistance to breakage. Spruces cones are well-utilized by a variety of wildlife. Black spruce is also particularly tolerant of wet conditions and an appropriate plant for revegetating deforested riparian areas. For all the above reasons, spruce will be among the species considered for planting in wetter riparian areas.

7) Northern Hardwoods

Northern Hardwoods include sugar maple, black and yellow birch, beech, and white ash growing on fertile sites on thick, moist, moderately well-drained, fine, sandy loams. Although they have survived insect attacks, dieback, acid deposition, and increased ozone concentrations, the perpetuation of these stands has been most heavily influenced by wildlife impacts. Seeds that manage to escape animal consumption and germinate into seedlings, with the exception of black birch and beech, were browsed heavily by deer during the previous decade. Because this type often grows in the moist bottomlands, mature trees are often girdled or felled by beaver, especially where deer browsing has eliminated other food sources. While there are a few pure stands of these species, they are usually found scattered throughout other types and will receive preferential treatment over most other species, due to their rare occurrence.

5.2.4.3 Summary of Planned Silvicultural Activities

The following summarizes the silvicultural strategy to be applied in the Quabbin forest over the next decade:

1. The total holding is ~58,000 acres, ~12,000 of which are unmanaged (islands, wetlands, steep slopes, designated natural areas), so that approximately 46,000 are considered manageable. As areas are assessed for management, small reserves from a few trees to multiple acres will be added to the unmanaged category, which may rise to 25% or more of the total holding as a result. The overall (and continuing) objective is to diversify age structure in the managed area by regenerating approximately 1% annually, or about 400 acres. This cutting will be restricted in several ways, described below.

2. DWSP will not regenerate more than 25% of any given subwatershed within any given 10 year period (this is an application of the results from research on paired watershed studies, which

conclude that with Conservation Management Practices (CMPs) in place, there is generally no increase in water yield, which in turn implies no increase in sediment or nutrient transport, until 25-30% of a watershed forest's basal area is cut within any given 3-10 year period (Ice and Stednick, 2004)).

3. Silvicultural practices will occur within three management zones:
   a. **Zone 1** includes the buffer strips along public roads, the variable width filter strip along streams and water bodies, and DWSP limits within filter strips around all vernal pools, and the area within 400 feet of the bank of the reservoir or within 200 feet of the bank of a tributary to the reservoir.
   b. **Zone 2, the Intake Protection Area** includes two protection areas, around the CVA and Shaft 12 intakes. For the CVA, this zone includes land within the watershed that is within ½ mile of the reservoir portion of the Quabbin Pathogen Control Zone. For the Shaft 12 intake, this Intake Protection Zone is the land that is within ½ mile of the intake, but also no further east than the watershed divide that sheds water either to the west or the east of the south baffle dam. The CVA Intake Protection Zone includes 2,435 acres, 695 of which are also in Zone 1. The Shaft 12 Intake Protection Zone includes 128 acres, 39 of which are also in Zone 1.
   c. **Zone 3** is the land that is outside Zones 1 and 2 and hydrologically most remote from the reservoir and intakes. This zone covers ~36,000 acres, or about 77% of the manageable area.

4. Cutting will be limited in all cases as follows:
   a. Zone 1 – single tree or small group selection up to 0.5 acre
   b. Zone 2 – single tree, small group, and patch selection up to 1 acre in size
   c. Zone 3 – single tree, small group, and patch cutting, with the majority in a diverse mix of groups and patches under 2 acres in size and a maximum of 10% of the total annual cutting (no more than 40 acres) in larger openings greater than 2 acres in size.

5. Cutting will be further limited as follows:
   a. Each year, at least 90% (360+ acres) of the regeneration cutting will be in single tree or small group selection harvest less than 2 acres in size, and completed within Zone 1 (single tree selection and small group selection up to 0.5 acre only), Zone 2 (single tree selection and small groups not larger than 1 acre), and Zone 3 (single tree selection and small groups with a target size of 1 acre or less, but not larger than 2 acres).
   b. In response to green certification recommendations that structural diversity at the landscape level should include some larger single-aged blocks and concerns for declining migratory birds and other species that require early successional habitat and certain silvicultural situations, each year up to 10% of the regeneration cutting will be in patches greater than 2 acres in size and completed within Zone 3 only.

6. In addition, up to 200 acres of intermediate thinnings will occur each year where necessary to increase group or stand vigor.

5.2.4.4 Comparison of Forestry in the 1995-2004 versus the 2007-2017 Quabbin Land Management Plans

- In the 1995-2004 Land Management Plan, the vast majority of the regeneration cutting was concentrated in small groups ranging up to 1 acre in size. The proposal was to regenerate 500-600 acres per year during the 1995-2004 management period; 388 acres per year were actually regenerated on average, plus 640 acres of preparatory or intermediate cutting. That plan allowed full overstory removal in special cases (red pine on disease-prone wetter sites; old grazing areas

with low species diversity; and old field white pine stands with very poor form and vigor), and limited this type of cutting to a maximum of 50-60 acres of the managed forest annually.

- The current plan calls for regenerating 400 to 450 acres annually, still primarily in openings from single tree to about 2 acres in size, and with options to create larger openings where the site is hydrologically removed from the Reservoir and where these can be justified for silvicultural reasons or to enhance horizontal diversity in support of uncommon species. This target acreage would annually regenerate about 1% of the managed forest area during the coming decade. Openings larger than 2 acres would not total more than 10% of the annual regeneration cutting (not more than 40 acres per year). Intermediate thinnings are proposed on up to 200 acres annually.

- The proposed 2007-2016 LMP is a continuation of the overall strategy of diversifying the forest structure, but includes a stronger correlation between harvesting and hydrologic sensitivity through an on-going analysis of the percentage of any given subwatershed that has been treated in the previous decade, and through the establishment of the hydrologic zoning system described in Section 5.2.3.3.

Table 43: Harvesting at Quabbin Fiscal Years 1996-2005

Fiscal Year	Total Acres Harvested	Total Acres Regenerated	Board Feet	Cords	Tons	Revenue
1996	659	85	2,645,494	1,994	3,458	$306,048
1997	1,274	682	7,447,357	3,495	9,215	$727,993
1998	1,253	385	4,894,431	4,908	1,569	$677,017
1999	1,332	382	5,327,581	4,974	7,410	$567,504
2000	1,110	419	5,042,700	3,884	6,221	$1,028,977
2001	745	371	4,532,600	2,703	8,059	$524,075
2002	808	380	4,196,880	2,646	7,665	$571,601
2003	1,003	397	5,575,799	4,150	8,645	$704,882
2004	890	337	2,873,334	4,095	5,170	$381,540
2005	1,205	439	5,146,694	5,598	6,864	$757,708
TOTAL	**10,279**	**3,877**	**47,682,870**	**38,447**	**64,276**	**$6,247,345**
Average	*1,028*	*388*	*4,768,287*	*3,845*	*6,428*	*$ 624,734*

Table 44: <u>Example</u> of a *Possible* Cutting Pattern during FY 2007-2017, by Forest Management Zones

Type	Zone 1	Zone 2	Zone 3	TOTAL	Percent of type total
Regeneration cuts	*Acres by Treatment Type*				
Single tree	50	10	15	75	18.75% of regen cuts
Small groups to 0.25 acre	20			20	5.00% of regen cuts
Small groups to 1 acre		10	185	195	48.75% of regen cuts
Small groups to 2 acres			70	70	17.50% of regen cuts
Patches 2-5 acres			20	20	5.00% of regen cuts
Patches 5-10+ acres			20	20	5.00% of regen cuts
Total regeneration cuts by zone	*70*	*20*	*310*	*400*	
Intermediate thinnings	35	10	155	*200*	
Treatment totals	*105*	*30*	*465*	*600*	

5.2.5 Current Threats: Forest Insects, Diseases, and Invasive Exotic Plants

In the Quabbin forest, insects and disease are a major problem only when their impacts conflict with the Division's objective of creating and maintaining a watershed protection forest. Generally, only large-scale outbreaks that threaten to alter tree species diversity or forest structure are of concern. Chestnut blight was such a disease. It was first discovered in the Quabbin forest in the early 1900s and fairly rapidly eliminated all overstory trees of the species. Salvage of the dead and dying trees began immediately in the hope of protecting the yet uninfected chestnuts. Before the blight, chestnut was one of the dominant trees in the forest. Today, it is essentially a minor shrub, playing a much less significant role in the protection of the water supply and in support of biological diversity through its significant production of mast. Fortunately, both of these roles have been replaced by the now common oak component of the Quabbin forest.

The gypsy moth is another example of a serious pest. It was first found in the forest surrounding the Wachusett Reservoir in 1910. A great deal of effort was spent in trying to control the inexorable spread of this insect. Epidemics of this insect can result in significant mortality of a wide range of tree species in both the overstory and understory resulting in alterations to forest structure, composition and vigor. Insect defoliations have also been demonstrated to affect water quality. Research from North Carolina has demonstrated that concentrations of stream nitrate nitrogen were elevated 4-5 times background rates during peak defoliations by cankerworm (Swank, et al., 1981).

Both the fungus that causes chestnut blight (*Cryphonectria parasitica*) and the gypsy moth (*Lymantria dispar*) are introduced organisms that came to the watershed forests without their co-evolved complement of predators and parasites; a recipe for the development of an altered ecological condition. Other examples that have in the past affected or are currently affecting the Quabbin forest include Dutch elm disease, beech bark disease, and white pine blister rust. The most significant current threat to the Quabbin forest is the hemlock woolly adelgid, a pest for which the Division has developed the policy that follows in Section 5.2.4.1.

5.2.5.1 Hemlock Woolly Adelgid and DWSP Policy for Managing Impacts

Hemlock woolly adelgid, *Adelges tsugae*

The hemlock woolly adelgid (HWA; *Adelges tsugae*) is a small aphid-like insect native to Japan. It arrived in North America in the 1920s, and was first recognized on the east coast of the US in 1951 and in Connecticut in 1985. It is spreading in all directions across the range of eastern hemlock (*Tsuga canadensis*). It is a serious pest on both eastern hemlock and Carolina hemlock (*Tsuga caroliniana Engelm*), but does not seriously injure the western hemlocks (*Tsuga heterophylla* or *Tsuga mertensiana*). Chinese hemlock (*Tsuga chinensis*) planted at the Harvard University Arnold Arboretum resists HWA (Peter Del Tredici, Senior Research Scientist, Arnold Arboretum, personal communication).

Eastern hemlock grows throughout the watersheds under the care and control of DWSP, but is concentrated in three forest types: relatively pure hemlock stands; in mixes where white pine dominates; and in mixes where hardwoods dominate. Forest typing completed in the past several years indicates that out of the approximately 58,000 acres of Quabbin watershed forest that DWSP controls, 1,642 acres (~3%) is in pure hemlock stands; an additional 5,434 acres (~9%) is in stands with a significant component of hemlock in mixes with other softwood and hardwood species. About 9% of the overall basal area on Quabbin permanent inventory plots was in hemlock in 2000, and

hemlock sawlog volume based on those plots was approximately 30-35 MMBF. On DWSP properties on the Ware River watershed, about 7% of the overall stocking is in hemlock, the vast majority of which is in mixed white pine/hemlock stands, which total approximately 4,325 acres. A rough estimate puts the hemlock volume at Ware River in excess of 10 MMBF. Hemlock is <2% of the stocking, on just over 120 acres of hemlock/hardwood type on the Wachusett Reservoir watershed. A significant portion of the hemlock stocking overall is located on wet soils, on steep slopes, or in riparian zones, some of which are steep-sided ravines, while other stands are on drier and flatter terrain.

The hemlock woolly adelgid is a particularly troublesome pest on DWSP watersheds (and elsewhere) for several reasons:

1. The insect is without natural enemies in the northeastern US. Several potential biocontrols have been imported from Japan and China, reared in laboratories, and released at HWA sites, but to date these have had very limited impact for a variety of reasons. Successful chemical controls are mostly limited to systemics and dormant oil spraying. These can be effective in ornamental plantings, but are virtually impossible to apply in an extensive forest infestation.

2. The HWA is parthenogenic, which means that every adult is capable of reproduction. Each adult lays 50-300 eggs, typically about 100. Furthermore, the population successfully completes two generations within a year. The first eggs are laid in March and April. Crawlers hatch from these eggs and begin feeding at the base of needles, where they remain throughout development. This generation matures in mid-June, when adults lay eggs again. These hatch in July, move to new hemlock growth and then become dormant until October, when they begin feeding again. They continue feeding throughout the winter (the species evolved in high elevations in Asia and tolerates low temperatures), maturing by spring to begin the process again. Mortality rates observed during the winter of 2002-2003 were as high as 75% (Jen Pontius, USDA FS, personal communication), but the fecundity of this species will likely allow its rapid recovery.

3. While hemlocks that are under attack eventually become incapable of supporting the infestation, resulting in a population crash in the HWA on that tree, these trees are also incapable of recovering from this level of damage. Trees that are infected may die within 4-5 years, although some may persist for longer in a weakened condition. The insect attacks all ages of trees, though it prefers younger foliage. There is no clear evidence of resistance sufficient to allow any individual eastern hemlock tree to survive once infested with the hemlock woolly adelgid (Orwig et al., 2002).

4. Of particular concern to DWSP are location where hemlock dominates the riparian zone along streams leading to the reservoirs or the Ware River. Loss of this overstory may present short-term threats to water quality by raising stream temperatures and through uncaptured nitrogen and other cation losses following increases in nitrogen mineralization and nitrification rates. Regeneration may prevent significant losses to stream water.

5.2.5.1.1 Principle Issues From Current HWA Literature

1. All ages and sizes of Hemlock are susceptible to HWA infection, and infection will eventually kill the infected tree. Trees on poorer, drier, ridge top sites may die more rapidly than those on well-watered sites, but trees located on the full range of sites have become infected and ultimately died.

> Mortality was weakly related to aspect and stand size. Average mortality was highest on western aspects but exceeded 20% on most slopes. Remaining trees averaged over 50% foliar loss, with no significant

> difference among aspects… Results suggest that as HWA becomes abundant, stands on xeric aspects succumb rapidly, but that stand and landscape variables such as overstory composition and structure, slope, and elevation, exert little control over susceptibility or eventual mortality. (Orwig et al., 2002)

2. All approaches to management, including simply allowing HWA mortality to occur without intervention, result in changes to the forest floor that include increased mineralization and nitrification rates that produce more mobile inorganic nitrogen. To the extent that regeneration occurs in pace with, or in advance of mortality, available inorganic nitrogen is recaptured and immobilized by biomass accumulation. Consequently, it should be expected that the highest accumulation of inorganic nitrogen will occur in soils where heavy cutting occurs with little or no regeneration on the ground, while the more gradual conversion associated with either partial, preparatory cutting designed to stimulate advance regeneration or letting the stand die and regenerate without intervention should reduce both the volume and the duration of soil accumulations of inorganic nitrogen. The significance of these differences in soil nutrient accumulations to quality changes in adjacent surface waters is uncertain.

> The total amount of N captured in recent harvests was about five times greater than HWA-damaged [unharvested] sites and nine times greater than undamaged sites….Compared with undamaged sites, inorganic N pools increased only slightly in HWA-damaged sites, but increased tremendously following logging.…Net nitrification rates were 41 times higher in HWA-damaged sites, 72 times higher in recent harvests, and over 200 times higher in old harvests when compared with the near-zero rates in undamaged hemlock sites.…Relatively large amounts of ammonium and nitrate captured in recent harvests indicate higher N availability, less vegetative uptake, and a greater potential for N leaching. Hemlock harvesting imposed more abrupt microenvironmental changes, and rapidly reduced vegetative cover while chronic HWA infestation led to gradually thinning canopies. Both disturbances led to black-birch dominated forests, although logging resulted in greater amounts of shade-intolerant regeneration, higher soil pH and nitrification rates, and reduced forest floor mass. Pre-emptive cutting of undamaged forests may lead to greater N losses than those associated with HWA infestation or logging of deteriorated hemlock forests, because of reduced vegetative uptake. Silvicultural methods that allow for vegetation establishment prior to harvesting will probably lessen the ecological impacts of hemlock removal.…We predict in sites infested with HWA, the slow and progressive hemlock decline and gradual development of a hardwood understory may result in the least amount of nitrogen loss. Pre-emptive cutting of undamaged sites appears to pose the greatest threat for nitrate leaching, followed by logging of declining sites. (Kizlinski, et al., 2002)

> There is clearly a strong potential for significant losses of N and nutrient cations to soil water in hemlock stands with high mortality. These losses reduce site nutrient capital and may affect future productivity, especially on sites that were nutrient-poor prior to hemlock mortality. Nutrient losses to soil water may also lead to declines in surface water quality (i.e., increases in nutrient concentrations) in areas with significant proportions of hemlock and where hemlock is typically dominant in

> ravines and on steep slopes. Such effects on surface water quality will be particularly important to those managing forested watersheds that provide a domestic water supply. (Yorks, et al., 2000)

3. As is true with any overstory removal of trees, the loss of hemlock due either to salvage logging or defoliation and mortality results in an increase in soil moisture and subsurface flow, which also increase the likelihood of transporting both organic and inorganic nutrients to streams.

> Stand productivity and water use appear little impacted until an intermediate threshold of damage has occurred. Enhanced soil moisture availability may first be noticed toward the end of the growing season. Once trees reach heavily damaged status, water uptake and transpiration are severely reduced throughout the growing season, leaving substantially more water available for evaporation, runoff, and/or use by other plant species. (Kimple and Schuster, 2002)

4. There remains some uncertainty about the fate of individual hemlock stands. While trees eventually succumb once infected, the distribution of infection has been moderated at least by the variability in distribution vectors. Selected stands within large forests that have escaped infestation and remain healthy may be worth protecting, even at high cost. The possibility that they can persist beyond the infestation and provide landscape points from which hemlock might eventually recover, especially if natural and introduced controls eventually strengthen, should be considered (Orwig and Kittredge, 2005; U.S.D.A. Forest Service, 2005)

5. Scientists throughout the range of *Tsuga canadensis* are working to find and release safe predators shown to be effective in controlling HWA, including a wide variety of predatory coccinelid beetles and fungi. To date, these efforts have not produced controls able to keep pace with the reproduction and spread of HWA. However, our experiences with *Lymantria dispar* (gypsy moth) and the dramatic reduction of its threat brought on by the growth of *Entomophaga maimaiga*, a population-controlling fungus, raise a glimmer of hope that science and natural systems might combine to moderate the demise of the hemlock population throughout its range.

> Management of forest pests such as HWA in natural areas relies on natural controls that are simple to use and of low cost. To date the major emphasis of research in this area has been on the rearing and release of exotic coccinelid predators. However, rarely will one biological control organism—a "silver bullet"—effectively suppress serious exotic pest populations below damaging levels. More realistic is a multifaceted approach using several compatible agents that together reduce pest populations. Entomopathogenic fungi comprise a group of naturally occurring organisms that penetrate, multiply within, and ultimately kill their insect hosts. These represent a group of promising, but as yet underutilized biological control agents for management of HWA and other exotic insect pests. Fungi are particularly promising for HWA management for several reasons. They have been found infecting HWA naturally in the eastern United States and in low-level adelgid populations in China. Many species of these fungi are relatively easy and inexpensive to mass-produce, and most have little or no negative impact on the environment, humans, or non-target organisms. Production is species and strain specific, and under ideal conditions, enough material for 1ha can be prepared for under $20.00 (Wraight et al., 2001). Naturally occurring epizootics caused by fungi have been

observed in populations of scales and various aphids demonstrating the potential for their use. An additional benefit of entomopathogenic fungi is their potential to persist in an infected population, providing an ongoing chronic fungal infection. Such conditions may cause an overall reduction in health and fecundity of the pest species. This stress may sufficiently reduce the pest population to a more manageable level—a level perhaps that coccinelid predators could reduce even further. (Reid, et al., 2002)

5.2.5.1.2 DWSP Policy for Hemlock Management in Response to HWA

It is DWSP's primary objective to make forest management choices that conservatively protect the drinking water supply. Secondary objectives include the protection of biological diversity and meeting the market demand for renewable resources, in part to offset the costs of protecting the water supply. The policy outlined below factors in background information as well as these objectives, in attempting to conservatively address the hemlock woolly adelgid problem.

1. Because of the uncertainty associated with hemlock mortality and the possibility of natural or introduced biological controls, DWSP will not conduct pre-emptive harvests of hemlock. Forest stands containing greater than 50% stocking of hemlock will be monitored for the presence of HWA. When the majority (>50%) of the hemlock trees in an operable stand are infected with HWA, the stand will be considered to be infested and will be considered for a harvest/salvage operation. Exceptions include operable, infested stands within areas such as the Pottapaug Natural Area on the Quabbin Reservoir, where harvesting is generally excluded unless managers determine that it is needed to prevent the spread of an insect or disease to other parts of the watershed.

2. Due to water quality protection concerns and the likelihood of increased inorganic nutrient availability, the hemlock management policy in uplands will differ from management in wetlands and riparian zones.

In upland areas, DWSP will harvest operable, infested hemlock stands to salvage wood and to reduce potential fire and recreational hazards associated with large volumes of standing and falling dead wood, while working to meet management goals for diverse forest structure. Where possible, scattered healthy overstory hemlock trees will be retained. These salvage operations will be designed to provide enough light to stimulate a diversity of shade intolerant species to compete with the common black birch regeneration response. Enrichment planting may be used in these upland areas to strengthen the diversity of the regeneration response.

DWSP will not cut infested hemlock stands located in seasonally flooded wetlands, and will avoid running equipment in hemlock stands growing on hydric soils, except when these soils are dry or frozen enough to carry logging equipment without damage. In riparian areas, cutting practices regulations limit cutting to 50% of the basal area, thus limiting the opportunity to stimulate shade intolerant regeneration except by increasing cutting adjacent to the filter strip. Harvesting stimulates mineralization and nitrification, leading to higher inorganic N pools. Black birch is competitively enhanced by high N levels and moderate light levels. Therefore, partial harvesting in riparian areas may favor black birch rather than diverse regeneration, the opposite of the desired effects. The Division has experimented with planting in conjunction with partial cutting in riparian zones, and is working to document examples in which these trees have successfully competed with natural black birch regeneration. Riparian areas will eventually lose their hemlock to HWA, but leaving them to gradually die may reduce the risk of nutrient transport to adjacent streams, although this has not yet been adequately documented. In light of all the above, DWSP will not cut within the variable width filter strip defined by Chapter 132 regulations during salvage

operations in hemlock stands infested with HWA, unless hemlock occupies less than 30% of this filter strip, in which case up to 20% of the filter strip stocking may be cut from the non-hemlock species, to add structural diversity. This policy will be in effect until evidence from stream and soil water sampling and/or regeneration research recommends modifications.

In summary, DWSP policy regarding management of hemlock includes:

1. Monitoring of stands with greater than 50% stocking in hemlock for presence of HWA.
2. Conducting salvage cuts only in infested stands, defined as stands in which the majority of the hemlock trees are infected.*
3. Designing salvage cuts to stimulate regeneration of both shade tolerant and shade intolerant species, while retaining scattered healthy hemlock individuals, and attempting to leave sufficient stocking of other species to meet forest structural goals.
4. Leaving the variable-width filter strip (as defined in Chapter 132) uncut in hemlock salvage operations, except when hemlock occupies less than 30% of that filter strip, in which case up to 20% of the filter strip stocking may be cut from the non-hemlock species.
5. Avoiding hemlock salvage in seasonally flooded wetlands and keeping equipment off of hydric soils in hemlock stands except when they are dry enough or frozen enough to support logging equipment.

5.2.5.2 Other Insect or Disease Threats

There are many insects and diseases present in the Quabbin watershed forests, but most of these are well-controlled, endemic features of the local ecosystem and do not present significant, landscape level threats. Examples include such insects as the eastern tent caterpillar and fall webworm, hemlock looper, oak leaf skeletonizer, and diseases such as the target canker (*Nectria*) in black birch. Some pests have been brought into the system from the outside and either have already had a major impact (chestnut blight; Dutch elm disease) or have been around long enough that the system has developed controls that appear to be limiting further disastrous impacts (gypsy moth). Still others are in the middle of a gradual but ultimately devastating impact on certain species (beech bark disease, ash yellows). Finally, some long-present pest problems that have been brought under control in the past are threatening revival, e.g., white pine blister rust.

There are also threatening insects and diseases that have not yet been identified on the watershed but that have some potential to cause significant damage if they become established. The following are examples, with brief notes on their preferred hosts, biology, and potential impacts are listed below:

- Sudden oak death is a fungal disease that has killed oaks and a variety of other trees in California in as little as 2-4 weeks following infection (thus "sudden death"). So far, this disease is a problem in the western U.S., but there are concerns that it could travel via cross-continental nursery trade. With demonstrated susceptibility to this disease, the red oaks that dominate large areas of the Quabbin forest would likely be severely impacted if this disease arrives on the watershed.

- Asian long-horned beetle is a large insect (0.75-1.5 inches long) with long black and white banded antennae. It was introduced in New York City in 1996 via overseas packaging materials and has also been discovered in Chicago, New Jersey, and Toronto, among others. Millions of dollars have been spent trying to locate and destroy all infected trees in order to contain and

* Because these are salvage operations that require more rapid response than typical silvicultural operations, the DWSP internal lot review process will be conducted within four weeks of the identification of a stand as sufficiently infested to warrant a salvage cut. This determination will be made by field consultation between Forestry and Natural Resources Staff using methods mutually agreed upon to determine the condition of the stand.

eventually eradicate this insect from the U.S. If it escapes these efforts, it is potentially devastating to maples and birches.

- Winter moth has recently reached outbreak levels in coastal areas of Massachusetts. While it has not yet moved westward, it is potentially a serious problem. In Nova Scotia, it has been responsible for mortality of 40% of oak stands and is known to feed on oaks, maples, basswood, ash, and apples (www.umassgreeninfo.org/fact_sheets/defoliators/winter_moth.pdf). Control efforts on the east and west coasts of the US and Canada have included both biological controls and insecticidal chemicals.

- Sirex woodwasp was only recently discovered (2004) in New York state, the first discovery in North America of this insect, which is on the top ten list of worst forest pests around the globe. Most pines, including Eastern white pine, are susceptible, and there are no known native natural controls for this insect. New York State has recently launched a comprehensive program to try to limit the spread of this insect.

5.2.5.3 Invasive Plants

See Section 5.5.6 for a complete review and discussion on invasive plants.

5.2.5.4 Salvage Policy

Some disturbances that move through the Quabbin forest can damage standing trees in ways that result in a rapid decay in their merchantable value, sometimes in combination with an increase in fire danger, hazards to users of the forest, or blockage of access roads. Strong winds and heavy snow or ice can break or fell trees in haphazard patterns that create access dangers. Insect defoliations can kill trees rapidly and create short-term fire hazards as well as access danger. Some species lose value rapidly, for instance when white pine is felled or killed by wind during warm seasons, when the blue-stain fungus can infect the wood rapidly, significantly dropping its merchantable value.

It is Division policy that salvage cutting will only take place in forest areas that have lost (or are likely to lose in a short time period) 50% or more of their stocking, due to storms (ice, snow, or wind), fires, insects, or pathogens. Salvage sales will not go through the normal annual internal review process, but will be subject to approval by the Regional Director, the Natural Resources Section Director, and the Chief Forester before cutting can start. Salvage sales will only take place on an emergency basis when there will be significant loss of wood product value or marketability by waiting to sell these products at the next scheduled timber showing, or when access issues caused by damaged or fallen trees need immediate resolution.

5.2.6 Conservation Management Practices (CMPs) for Watershed Forest Management

NOTE: DWSP utilizes the Canadian term "Conservation Management Practices" instead of "Best Management Practices." Both terms refer to efforts to create resource-protecting standards for management activities.

Forest management at Quabbin is done to improve watershed protection. As a minimum Conservation Management Practice, DWSP will uphold the standard that no measurable negative impact will occur on the quality of water, as measured at locations downstream from a logging project. DWSP staff will measure water quality periodically upstream and downstream from logging projects to assure compliance with this standard. Described below are the specific practices designed to accomplish this compliance. It should be noted that the DWSP meets or exceeds the requirements of both the Forest Cutting Practices

Act and the Wetlands Protection Act (MGL ch. 132 and 131). Whenever these regulations are revised, DWSP management practices will meet or exceed the revised standards.

Strict adherence to DWSP's Conservation Management Practices (CMPs) ensures that forest management is conducted in a manner that does not impair water resources or other natural/cultural resources on the watersheds. Silvicultural practices, as described in the management plan, are employed to bring about specific forest conditions. These practices require the cutting and removal of overstory trees to diversify structural and species compositions and to maintain the vigor of the residual overstory. The forest is treated, on an average, every 20-30 years and at that time, 1/3 or more of a stand may be removed to establish and release forest regeneration. The process of removing trees can impact the forest and soils essential to protecting water quality if not carefully regulated.

Among the areas of greatest concern is the placement of forwarder and skid roads and log landings, where logging work is concentrated. Proper location of these in relation to streams, rivers, reservoirs, ponds, vernal pools, and bordering vegetated wetlands is important so that soils do not move from these areas into water or wetland resources. Beyond this principal concern, Conservation Management Practices are designed to diminish the negative impact of silvicultural operations on the residual vegetation, to minimize soil compaction during these operations, and to keep potential pollutants out of the water resource.

5.2.6.1 Variables

There are many variables to consider when planning and conducting a logging operation, including equipment limitations, weather, soil depth, soil moisture, topography, silvicultural practices, vegetation, and operator workmanship. Variables such as weather, soil moisture, soil depth, topography, and existing vegetation are beyond human control. The constraints they place on logging must be factored into planning, and logging schedules and expectations adjusted accordingly. Variables such as equipment, silvicultural planning, and operator workmanship can be modified, for instance, by matching allowable logging equipment with the constraints of a given site.

5.2.6.2 Logging Equipment

Logging equipment has changed dramatically in the 40 years that forest management has been active on DWSP watersheds. The primary logging machine was once the 50-70 horsepower (hp) crawler tractor-sled combination. These tracked machines were 5-6' wide and weighed 5-7 tons. Today, most logging is done with 4-wheel drive articulated skidders or 4-8 wheel drive articulated forwarders with 70-260 hp, widths of 7-10', and weights of 6-24 tons (empty) or more. Skidders drag logs attached to a rear-mounted cable and winch or a grapple, while forwarders carry logs on integrated log bunks.

Other types of logging equipment include grapple skidders, wheeled and tracked feller-bunchers, and feller-processors. A grapple is an add-on feature that replaces the winch and cable with hydraulically operated grapple arms. Feller-bunchers cut trees and put them in piles, usually for removal by a grapple skidder. There are 3- or 4-wheel feller-bunchers that must drive up to each tree for felling, whereas tracked models can fell a tree 10-20 feet from the machine. A feller-processor fells, de-limbs, and cuts trees, leaving piles of logs or cordwood, which are retrieved by forwarders. Machines that process felled trees into logs, pulpwood, or firewood are generically referred to as "cut-to-length", or C.T.L., machines.

Small skidders are useful for logging on watersheds whereas larger 100-230 hp models, that weigh from 8-18 tons and are 8-10' wide, are usually too large and heavy for stand and soil conditions. Combinations of small, maneuverable feller-bunchers and forwarders, small skidders and forwarders, and small tracked or rubber-tired feller-processors and forwarders have all worked successfully on DWSP watersheds. **Table 45** shows typical combinations of equipment that work on various types of harvesting operations on DWSP watersheds.

Table 45: Harvesting Methods/Equipment Used on DWSP Watershed Lands

Method/Equipment	4-8' Cordwood or pulpwood	8-20' Sawlogs, fuelwood, pulpwood	Whole-tree
1. Chainsaw felling with 4WD pickup truck	✓		
2. Chainsaw felling with cable skidding	✓	✓	✓
3. Chainsaw felling with forwarding	✓	✓	
4. Rubber-tired, four-wheeled feller/buncher with grapple skidding		✓	✓
5. Rubber-tired, four-wheeled feller/buncher with chainsaw limbing and forwarding		✓	
6. Rubber-tired, three-wheeled feller/buncher with grapple skidding			✓
7. Tracked feller/buncher with grapple skidding		✓	✓
8. Tracked or rubber tired CTL with forwarding	✓	✓	

In an effort to specify equipment that is appropriate on specific soils and within specific forest types, DWSP has determined ground pressure and width measurements for most of the equipment common to the area, and specifies restrictions, where needed, in timber harvesting contracts. Widths are either from direct measurement or from manufacturer's specifications; ground pressures are based upon a formula that combines machine weight and weight of an average load of logs with an estimated footprint for the tire size specified, at an average tire inflation pressure. Examples from this rating system are listed in **Table 46** (skidders) and **Table 47** (forwarders).

Rubber-tired skidder.

Forwarder with tracks

Table 46: Sample Skidder Sizes and Ground Pressures

Machine Model	Tire Size (inches)	Width (inches)	Ground Pressure (lbs/sq in.)
Cable skidders			
TimberJack 208	23.1 x 26	102	4.9
JohnDeere 440C	23.1 x 26	102	5.0
Franklin 105XL	23.1 x 26	110	5.3
TreeFarmer C4	18.4 x 26	93	6.5
JohnDeere 540	23.1 x 26	105	6.6
CAT 508GR	23.1 x 26	106	7.1
Clark 665	23.1 x 26	114	7.9
Clark 665	18.4 x 24	104	9.5
TreeFarmer C6	18.4 x 34	97	10.1
CAT 518	18.4 x 34	99	11.2
Grapple skidders			
Franklin Q80	30.5 x 32	131	7.9
Prentice 490	24.5 x 32	118	10.0
Tigercat 610	24.5 x 32	115	9.7
John Deere 648G	24.5 x 32	123	8.2
Caterpillar 525C	30.5 x 32	133	8.2

(Sources: Firestone Tire Co. – LS-2, Forestry Dimension Special Table)

Table 47: Sample Forwarder Sizes and Ground Pressures

4 Axle Forwarders	Tire size (mms x inches)	Width (inches)	Ground pressure (lbs / sq. inch) *Unloaded*	*Loaded*	*Loaded, with Eco Tracks*
Rottne/Solid F12	700 x 26.5	112	5.6	10.1	6.8
John Deere 1110	600 x 26.6	107	5.3	14.5	12.4
Timberpro 815	700 x 26.5	113	3.4	14.5	10.3
Valmet 860	600 x 22.5	110	5.5	17.4	9.9
Caterpillar 574	700 x 26.5	111	5.6	15.7	9.3

(Sources: Caterpillar Inc, Forest Products Forwarders Ground Pressure Table: Forestry Research Institute of Sweden (Skogforsk) & Forest Engineering Research Institute of Canada (FERIC)

Some of the logging equipment available is too large or heavy to meet DWSP requirements in certain vegetation or soil conditions; some is limited by terrain. Matching the equipment with the site conditions so that minimal damage occurs is critical to the success of watershed silvicultural activities. DWSP specifies equipment requirements for each site in its harvest bidding. This includes machine width and ground pressure limits, as well as specific equipment requirements. While each site has unique conditions

that require the experienced judgment of the forester to predict impacts, ground pressures are generally limited to 8 pounds per square inch or less on soils that are less well-drained. Machine widths are limited in intermediate cuttings of dense, unthinned stands with moderate topography, most typically to around 8.5 feet.

An example of a "preferred logging system," that accomplishes DWSP goals under difficult conditions is a small C.T.L. processor and forwarder combination, used for thinning dense pine plantations on a variety of soil conditions. Both machines are able to work in these conditions with minimal root, stem, crown, or soil damage. In addition, these machines can successfully work around walls and foundations and do not require a landing, as logs are stacked on the roadside. This combination can also work in previously thinned stands that have an understory of young trees, with minimal damage to the young growth. Generally, when trying to save and promote growth of advance regeneration, fixed head processors are required. Dangle heads are allowed when damage to advance regeneration is not a concern, due to its scarcity or poor condition.

Rubber-tired C.T.L. machine with a dangle head processor

While smaller tracked feller-processors are limited to stable ground conditions (few rocks and gentle slopes) and trees less than 16" DBH, current models can fell trees up to 30" DBH and come equipped with self-leveling cabs that allow work on slopes up to 30% and rubber tires that allow work on rocky ground. In old stands where the trees are generally large, hand felling is necessary. Multi-aged stands will always have many more stems/acre than the present even-aged stands and consequently are more difficult to work in without damaging residual trees. A combination of a winching machine and forwarder works well in multi-aged stands. This logging system addresses the problem of damage to the residual trees associated with long skid roads.

Table 48 summarizes some of DWSP's effort to match equipment and logging systems with site conditions. The methods listed in **Table 49** are taken from **Table 46**.

Table 48: Harvesting Methods/Equipment Used in Various Soil/Terrain Combinations

Slope	Excessively drained soils	Well-drained thin soils	Well-drained thick soils	Moderately well-drained soils	Poorly to very poorly drained soils
Level to 10% grade	Methods 1-8	Methods 1-8	Methods 1-8	Methods 1-8 with frozen or dry soils only; ground pressure < 8 lbs/sq. in	Generally not worked with machines
11-20% grades	Methods 2-6	Methods 2-6	Methods 2-6	Methods 2-6 with frozen or dry soils only; ground pressure < 8 lbs/sq. in	NA
Slopes greater than 20%	Method 2	Method 2	Method 2	NA	NA

5.2.6.3 Silvicultural Planning

Silvicultural plans have to address present and future cutting practices, landscape aesthetics, cultural resources, wildlife resources, wetlands, and rare or endangered species. While the protection of non-tree resources is of particular concern, the most difficult aspect of planning concerns the maintenance of multi-age stands of trees. These stands have great numbers of trees, especially seedlings, saplings, and poles that are more easily damaged than larger trees. The positioning of permanent logging roads, landings, and small and large group cuts is crucial to the long-term success of silviculture. Logging operation success and optimal protection of water resources are dependent upon careful advance planning (see **Figure 17** for an example of silvicultural planning). For example, the best possible stream crossing is the one that is avoided by planning.

A well-planned harvest

5.2.6.4 Operator Workmanship

Operator workmanship is one of the most crucial and variable factors in forestry operations because good planning and preparation can be negated if operators perform poorly. Most loggers are paid on a piecework basis. Their paycheck does not always relate to how hard or how carefully they worked, but on the amount of wood that gets to the mill. DWSP, however, maintains tight control over loggers working on the watersheds and exercises its right to remove operators who fail to adhere to contract standards. Furthermore, every harvesting operation receives a written post-harvest inspection and evaluation report that is filed for future determination of the operator's commitment to good workmanship. It is important that foresters and loggers develop mutual respect that is based upon a shared commitment to the sustainable stewardship of the land over long periods of time.

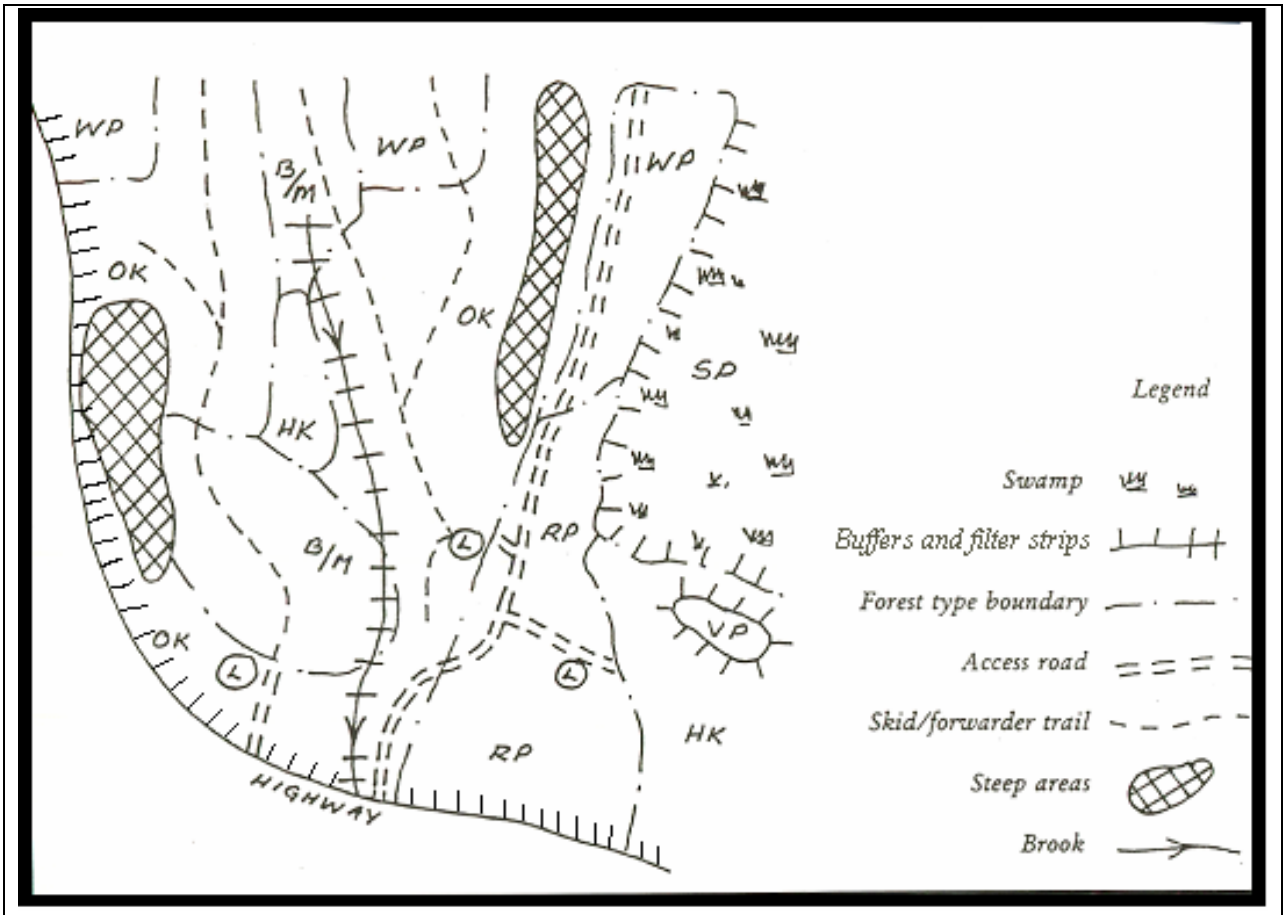
5.2.6.5 Filter Strips

Filter strips are vegetated borders along streams, rivers, or water bodies (including vernal pools) and represent the final opportunity to prevent transport of sediment or nutrients into streams or reservoirs from nearby roads or landings. When roads and landings are near water resources, filter strips are given special attention. Chapter 132 (Forest Cutting Practices regulations) requires a 50 foot filter strip, in which cutting is limited to 50% of the basal area and machinery is generally not allowed (exceptions include stream crossings). Chapter 132 regulations require increasing the filter strip based on slope conditions and along Outstanding Resource Waters (protected public water supplies) and their tributaries (excluding vernal pools and bordering vegetated wetlands), streams that are 25 feet or more from bank to bank, ponds of 10 acres or greater, and designated scenic rivers. DWSP meets these requirements and also increases the filter strip, based on both slopes and soils, for other areas not included in the definitions above. For example, on moderately and poorly drained soils the filter strip is increased 40 feet for each 10% increment of slope angle above 10%. On well-drained outwash and till soils the filter strip is increased 40 feet for each 10% increase in slope angle above 20%. Equipment may enter the filter strip in limited cases where streams must be crossed.

5.2.6.6 Buffer Strips

Buffer strips are retained and managed for aesthetic purposes along the edges of highways and public roads. Chapter 132 requires that within this strip, no more than 50% of the basal area can be cut at any one time and that no additional trees can be cut for five years. Buffer strips will be 50 feet except along designated scenic roads, where Chapter 132 requires them to be 100 feet in width.

Figure 17: Hypothetical Example of Silvicultural Planning



This approximately 200 acre area of DWSP forest contains separate stands of white pine (WP), hemlock (HK), birch/maple (B/M), oak (OK), spruce (SP), and planted red pine (RP). A fire in 1957 severely burned the lower 1/3 of the area, and the red pine was planted shortly after this fire. The topography and hydrography of the area include large areas of well-drained sandy soils, but also several small steep areas, a year-round brook, a swamp, and a vernal pool (VP). These areas are delineated with buffers where required. Work within these areas is restricted; steep areas and muck soils are not worked, and filter strips are only worked on frozen or dry ground. Fairy shrimp and mole salamander eggs have been found in the vernal pool, verifying its importance to wildlife. No work is proposed adjacent to this pool.

Except for the steep and wet areas, all the stands have received improvement thinnings within the past 30 years, and the understory has developed in response to deer control. Additional work in this area will release advance regeneration and/or establish new age classes by harvesting overstory trees in patches averaging 1 acre in size. Primary access is across the permanent road shown by a double dashed line. Single dashed lines are skidder and forwarder roads that have been used in the past and seeded and drained to prevent erosion. Landings are designated by a circled L, and represent areas used in the past and maintained as wildlife openings between operations. These roads and landings will be used again in current operations, and then returned to grass. There is evidence that the landings have been used between operations by wild turkey.

5.2.6.7 Wetlands

DWSP's forest management operations will comply with all the requirements of the Wetlands Protection Act, MGL Ch. 131 s 40, and the Forest Cutting Practices Act MGL Ch. 132 s 40-50 for cutting in wetlands (including bordering vegetated wetlands and freshwater wetlands as defined in the most current revision of Ch. 131 and 310 CMR 10.00, and as these are revised). Generally, activities that are not conducted under a Ch. 132 Forest Cutting Plan but will alter wetland resource areas or land within a 100 foot "buffer zone" beyond the water or the bordering vegetated wetland are subject to approval through the filing of a Notice of Intent with the local conservation commission.

All DWSP silvicultural activities that involve wetland resources are conducted under a Chapter 132 cutting plan, and therefore are exempt from Chapter 131 procedures, with the exception of limited amounts of work that does not include harvesting, including planting, pruning, and pre-commercial thinning and maintenance of boundaries and fire breaks. All of these latter activities are defined as "normal maintenance of land in agricultural use" by Chapter 131, and are therefore exempt from its filing procedures.

Chapter 132 requires a 50 foot filter strip along all water bodies and Certified Vernal Pools (see Section 5.4.3.1.1 and **Figure 18**), but allows harvesting in wetland areas provided that no more than 50% of the basal area is cut and the ground is only traveled by machinery when it will support that machinery (when it is frozen or dry). In addition, DWSP does not allow machinery within low, flat wetland forest with deep muck soils that are seasonally flooded, even though statewide regulations allow work in some of these areas during frozen or dry conditions. Most of the muck soils on DWSP lands at Quabbin are included within the designated wetlands on the watershed. DWSP has identified and mapped 3,012 acres of wetlands within the Quabbin property, which are generally avoided when lot boundaries are drawn for proposed annual silvicultural operations. DWSP also adheres to the statewide recommended practices for protection of vernal pools, including a 50 foot shade zone and a 200 foot buffer (see **Figure 18**).

Figure 18: Timber Harvesting Guidelines near Vernal Pools.

Adapted from guidelines that were cooperatively developed by foresters and wildlife biologists in Massachusetts.

Vernal pools provide critical habitat for a number of amphibians and invertebrates, some of which breed only in these unique ecosystems, and/or may be rare, threatened or endangered species. Although vernal pools may only hold water for a period in the spring, the most important protective measure is learning to recognize these pool locations, even in the dry season. Foresters can then incorporate the guidelines below in their plans to ensure that these habitats thrive.

Vernal Pool and Depression *No activity*

Objective 1: Maintain the physical integrity of the pool depression and its ability to hold seasonal water.

1. Keep heavy equipment out of the pool depression at all times of the year. Rutting here could cause the water to drain too early, stranding amphibian eggs before they hatch. Compaction could alter water flow and harm eggs and/or larvae buried in leaf litter at the bottom of the depression.
2. Prevent sedimentation from nearby areas of disturbed soil, so as not to disrupt the pool's breeding environment.
3. Keep tops and slash out of the pool depression. Although amphibians often use twigs up to an inch in diameter to attach their eggs, branches should not be added, nor existing branches removed. If an occasional top lands in the pool depression leave it only if it falls in during the breeding season and its removal would disturb newly laid eggs or hatched salamanders.

Shade Zone *100 foot buffer around pool edge*

Objective 2: Keep a shaded condition in this 50-ft. wide buffer around the pool depression. Amphibians require that the temperature and relativity humidity at the soil surface be cool and moist.

1. Light, partial cuts that can maintain this microclimate are acceptable; clear cuts are not.
2. Understory vegetation such as mountain laurel, hemlock, advance regeneration or vigorous hardwood sprouts after a harvest will help to maintain this condition. Avoid leaving only trees with small or damaged tops, or dead and dying trees.

Objective 3: Minimize disturbance of the forest floor.

1. Operate in this area when the ground is frozen and covered with snow, whenever possible. When operations must be scheduled in dry seasons, keep equipment 50 feet away from the pool depression and winch out logs.
2. Avoid operating during muddy conditions that would create ruts deeper than 6 inches. Ruts can be an impediment to migrating salamanders, some of which are known to use the same vernal pools and migratory routes for 15 to 20 years.

3. Minimize disturbance of the leaf litter and mineral soil that insulate the ground and create proper moisture and temperature conditions for amphibian migrations.

Low Ground Disturbance Zone *50-200 feet from pool edge*

Objective 4: As above, minimize disturbance of the forest floor in this area.

1. Operate equipment in this area when the ground is frozen or covered with snow, whenever possible.
2. Follow 2 and 3 from objective 3 above.
3. Locate landings and heavily used skid roads outside of this area. Be sure any water diversion structures associated with skid trails and roads do not connect to or cause sedimentation in the shaded zone or the vernal pool itself.

5.2.6.8 Logging Practices

A primary purpose of CMPs is to prevent or minimize the movement of soil to the water resource. During a logging operation, this is most likely to occur on a landing or skid/forwarder road. In these areas, the humus layer is sometimes lost and the soils may be temporarily compacted and channelized so that water will flow over the surface instead of passing through the soil. If the road is unwisely placed on a continuous slope, rainwater will increase in volume and velocity as it travels down-slope, scouring the path, removing soil, and creating a gully. If the road connects with a stream, the suspended soil may be carried much further. The result of careless logging practices can be erosion, increased stream turbidity levels, and deposition of the eroded materials downstream.

Logging practices and the human behavior necessary to avoid environmental degradation during logging are discussed in the following sub-sections. A cutting plan still relies upon the judgment and common sense of the logger and forester to make the right decisions in order to protect the land and associated resources.

5.2.6.8.1 Landings

A well-organized log landing

Landings are permanent sites that should be located on well-drained ground and soils that will support the logging equipment. Frozen soils are desirable because they support heavy trucks, but these conditions cannot be assumed to occur for more than a month or two each year. When located on moderately drained soils, landings are constructed with natural and/or man-made materials that prevent rutting and maintain a workable surface. This generally includes the use of crushed gravel, which allows water infiltration and supports heavy equipment, and may also include the use of "geo-textiles," woven road construction fabrics that prevent mixing of gravel with the soils below. Landings will not be accessed by skidder or forwarder roads that direct water into the landing. An effective barrier is maintained between the landing and access road (road ditch, hay bales, etc.) and landings are required to be smoothed and seeded after use.

5.2.6.8.2 Skid Roads

Skid roads are designed to be re-used and are therefore located on soils that can support the skidder, such as well-drained gravel or well-to-moderately-drained stony till soils. Some soils, regardless of their drainage capacity, are wet in the spring, early summer and late fall; harvesting must be scheduled for dry or frozen conditions. Skid roads are cut out before use and limbs left in the road to protect the soil. Skid roads are relatively straight to avoid damaging roadside tree stems and roots, but they are not allowed to carry water for more than 100 feet. Continuous grades are deliberately interrupted to divert rainwater off the road. Most skid road grades are less than 10%, but in some cases, climbing grades may reach a maximum of 20%. These steeper climbing grades are limited to 200 continuous feet. Downhill skidding grades are allowed up to 30% but for no more than 200 feet on grades greater than 20%. On skidding grades greater than 20%, which are not protected by frozen ground or snow cover, tree branches will be put on the road and other erosion-control measures taken as necessary.

Skidding distances are minimized to prevent excessive wear to roads unless frozen ground, snow, or rocks protect them. Skidder width and weight requirements are tailored to site conditions. The Division has rated many commercially available skidders by taking into account their horse power, weight, load capacity, tire size, and width to determine their suitability for logging on water supply watersheds (see Table 48 for examples). Skidder width ranges from 85-114 inches and loaded ground pressures range from 5-11 lbs/sq inch. Typically, machines with loaded ground pressures of 8 lbs/sq inch or less and widths of 102" or less are allowed on sensitive Division watershed lands. Skidding is stopped when rains or thaws make the soils unable to support skidders.

At the end of the logging operation or when work is suspended, skid roads are stabilized to prevent erosion. This task is accomplished through the construction of water bars. On slopes greater than 10%, water bars are spaced every 50 feet and on slopes less than 10%, they are spaced every 100 feet. It is sometimes difficult to regularly space water bars due to rocky conditions and lack of places to discharge water, so spacing may vary. Water bars are designed to meet two criteria:

- They must angle across and down the road to create a 3-5% pitch.
- They must discharge water to an area that drains away from the road.

A skidder can usually be used to construct water bars unless the soils are very rocky or ledgy. In rocky soils, they may have to be dug by hand. They do not have to be more than 6-8 inches deep, including the berm, unless they have to deflect more than the overland flow off skid roads (in which case depths are doubled). After completion of logging, water bars on skid roads are seeded during the growing season.

5.2.6.8.3 Forwarder Roads

Forwarder roads are located on soils that can support these machines. The layout of forwarder roads is more flexible than for skid roads because forwarders do not require straight roads. Forwarder roads can pass through the forest avoiding soft soils, trees, and sloping ground. Forwarder roads usually have less than a 5% slope with an occasional grade up to 10% for a maximum of 100 feet. Forwarder roads sometimes require rough preliminary grading to remove stumps and rocks. Forwarders were originally designed to stay on the road and pick up logs brought to the road by a skidder, but they also replace skidders when soil and/or vegetation conditions and cultural features cannot accommodate skid roads and skidder landings. In operations that combine skidders and forwarders, skidders operate the sloping and rough ground for distances of less than 1,000 feet, while forwarders operate on the more level terrain and handle long hauling distances. Water bar requirements for forwarder roads are the same as for skid roads.

5.2.6.8.4 Stream Crossings

Stream crossings are usually avoidable on DWSP watershed properties. Frozen conditions are favored whenever possible when streams must be crossed. These conditions not only protect the actual crossing, but also protect the approach and limit the amount of soil carried in machine tires or on skidded logs.

Skidder on a temporary bridge

Portable bridging is used to cross all streams with a continuous flow. This bridging consists of either pre-fabricated sections transported to the site (the Division has constructed portable bridge sections for use by private contractors), or site-constructed bridging. Past studies (Thompson and Kyker-Snowman 1989) have shown that machine placement and removal of crossing mitigation can move substantial sediments into the stream, especially where banks are steep or unstable. Therefore, it may be preferable in some conditions to construct mitigation on-site and without machinery. In either case, the bridging will be designed and constructed so as to prevent degradation of stream water measured downstream of the logging activity before, during, and after that activity.

Correct location of crossings is important in order to avoid soft soils that the machine may carry onto the bridge and into the water. Chapter 132 requires that all crossings be marked with paint or flagging and carefully mapped prior to filing of a cutting plan. All crossings are made at right angles to the streamflow. If frozen conditions are not available, then banks and adjacent soils are protected with tops of trees, poles, or other suitable material. In all crossings, any mitigation that involves structures that obstruct streamflow is designed and installed to accommodate the 25-year stormflow for the upgrade drainage. All temporary crossing construction is removed at the completion of the operation, and the site stabilized. Division foresters supervise the design, construction, placement, and removal of bridging or other mitigation and the proper protection of approaches, prior to the commencement of logging on the site.

Crossings of small, intermittent streams subject to MGL Ch. 131/132 protection (those portions downstream from the highest bog, swamp, wet meadow, or marsh in the drainage) are mitigated to prevent measurable downstream water quality degradation when these streams are flowing. These streams are only crossed without mitigation during frozen or dry conditions (when they are not flowing). No intermittent stream crossing will be allowed that would result in rutting or disruption of stream bank integrity. Chapter 132 further requires that all streams within 1,000 feet of the reservoir high water mark, including intermittent streams downstream of the highest wetland, must be crossed with portable bridging. Division foresters will frequently monitor all unbridged crossings, and discontinue or mitigate them if conditions deteriorate or downstream water quality is threatened.

DWSP crosses streams on a very limited basis. For example, from 1978 to 1990, the Division conducted 130 logging operations on the Quabbin and Ware River watersheds that involved 12 stream crossings (7 were across existing culverts, two were mitigated with DEM-approved techniques and three were crossings of intermittent streams in dry or frozen conditions).

Table 49 outlines the various stream-crossing situations encountered on DWSP watersheds and level of protection these crossings are given.

Table 49: Protection Measures Applied to Various Stream Crossing Situations

Type of Crossing Situation	Level of Protection		
	CMPs Only	Mitigate	Bridge
Intermittent stream, above the highest wetland in the drainage.	✓		
Intermittent stream, downstream of highest wetland, when not flowing; crossing further than 1,000 feet from reservoir high water mark.	✓		
Intermittent stream, downstream of highest wetland; crossing further than 1,000 feet from reservoir high water mark; when flowing.		✓	
Any intermittent stream with unstable banks/approach; regardless of flow conditions.		✓	
Intermittent stream, downstream of highest wetland, crossing within 1,000 feet of reservoir high water mark; regardless of flow conditions.			✓
Continuously flowing stream.			✓

"Wetland" refers to bogs, swamps, wet meadows, and marshes.
"Mitigate" includes use of poles, brush, or slabs placed in or beside a small stream to minimize equipment impacts on bank or streambed integrity.
"Bridge" includes installed or site-built structures that are above the stream profile and capable of keeping all equipment and harvested products out of the profile.

5.2.6.9 Point-Source Pollution Control

This section describes methods for control of petroleum product spills, human waste, and the disposal of rubbish generated by loggers and logging machinery maintenance. In addition, see Section 5.3.6.4, Pre-Planned Spill Response for Silvicultural Operations. The following are definitions used within this Section.

- Petroleum products: All machines are inspected by DWSP foresters for leaks prior to arrival and for the duration of their stay on the watershed. Checks are made of all hydraulic components, fuel tanks and lines, engine, transmission and axles. Trucks, forwarders, skidders and other equipment that carry petroleum products must have a sufficient number of petroleum-absorbent pads to contain a 10-gallon spill per machine on site. Immediate action to contain and stop any petroleum spills followed by prompt notification of the forester is required. The forester in turn contacts DWSP Environmental Quality personnel.

  All petroleum products that are not in machine storage are stored in safe durable containers and removed from the watershed at the completion of each day. Petroleum storage is only allowed in tanks designed, manufactured, inspected, and certified for commercial use. No re-fueling or servicing is allowed within the 50 foot filter strip along water bodies or within 25 feet of any wetland.

- Human waste: Deposition of human solid waste is not allowed on the watershed. Contract specifications require the use of a portable bathroom facility (a minimum of a "Coleman" type of

chemical toilet). The only exception to this policy will be the use of existing sanitary facilities on the watershed, which include those installed for recreational access.

- Rubbish: All waste material, including parts, packaging, lubricants, garbage, sandwich wrappers, and other litter must be stored in appropriate containers and removed daily from the watershed.

5.2.6.10 Fire Prevention

Fire prevention concerns both the forest and machinery. MGL Ch. 48, s. 16, a.k.a. the "Slash Law," adequately deals with the disposal of slash along boundaries, water bodies, wetlands, highways, roads and utility right-of-ways. Slash is not allowed within 25' of any stream, river, pond or reservoir. This law is also the DWSP standard.

Machine fires can spread to forest fires and cause water and soil pollution. Keeping a leak-free, well-maintained machine and having the proper fire extinguishers on the machine can prevent damaging machine fires. All machines are inspected for proper fire extinguisher and spark arresters by a DWSP forester before entering the site.

5.2.6.11 Protection of Residual Vegetation

Avoiding damage to roots, stems, and crowns of understory and overstory vegetation is essential in maintaining a protection forest. Damage can occur from unskilled tree felling, skidding, forwarding and the development of skid/forwarder roads. Skilled loggers and foresters can prevent most damage by using the proper logging system. Division contracts include the right to suspend operations due to operator inexperience or negligence.

5.2.6.12 Cultural Resource Protection

The protection of cultural resources fits well with watershed management because they both require low-impact logging systems. For example, small versatile equipment can reduce soil compaction and work around walls and foundations without damage. In many locations, there are no places for a landing due to cultural sites or poor soil conditions. Forwarders mitigate this problem by stacking logs on the roadside. The "preferred logging system" in these situations is a combination of cutting, lifting, or winching trees out, and forwarding them to an appropriate landing to meet cultural resource protection objectives (see Section 5.6 for a more detailed discussion on this subject).

5.2.6.13 Aesthetics

Aesthetics can be affected by all of the practices described in the above sections, and are the demonstration of workmanship quality. The maintenance of aesthetics reflects how loggers feel about their work and the land. This perspective cannot be forced, but it can be encouraged and learned. When work is done correctly it is not conspicuous, but when done carelessly it is obvious to all. DWSP watershed land is public property; the general public regularly passes through either along public roads or on roads within the watersheds. Attention to aesthetics is important everywhere, but most important along traveled ways. All slash and debris from fallen trees is kept 20' back from the road's edge or on the backside of a bordering stone wall. Landings are cleaned of unmerchantable tree debris. Care is taken to maintain large roadside trees and to promote replacement trees.

5.2.7 Control of Harvest Operations through Timber Sale Permit

5.2.7.1 Introduction

In conducting silvicultural operations that remove forest products from the forest, DWSP policy is to protect watershed resources such as water quality, soils, residual trees, and cultural resources. Both the timber sale permit, discussed in this Section, and Conservation Management Practices, presented in Section 5.2.5, address these concerns. In general, the Permit to Harvest Forest Products specifies the performance standards, whereas the CMPs explain how these permit specifications are met.

The timber sale permit consists of written specifications, pages detailing the forest products offered for sale, maps delineating the sale area, and a proposal page where a bid for the timber is entered and signed. The written specifications deal most directly with protecting watershed resources. Specifications consist of five parts: a.) General Conditions; b.) Water Quality Specifications; c.) Harvesting Specifications; d.) Utilization Standards; e.) Silvicultural Specifications; f) Harvesting Systems; and Bidding, Payment and Bonding Specifications. Parts b, c, and f pertain most directly to protecting watershed resources.

5.2.7.2 Water Quality Specifications

Water quality specifications are primarily concerned with petroleum leaks and spills and control of human waste. Petroleum products are required to be kept in suitable containers and removed from the work site each day, unless stored in tanks designed for fuel, such as those on the logging equipment. Oil absorbent pads and blankets are required on site and with all equipment, in order to intercept and immediately control a petroleum spill, should one occur. All associated refuse from maintenance and repair is required to be stored in appropriate containers and removed from DWSP lands as soon as possible. Human waste is required to be deposited in DWSP toilets or toilets supplied by the operator.

5.2.7.3 Harvesting Specifications

Harvesting specifications are concerned primarily with the process of cutting trees and removing forest products from the forest. DWSP timber harvesting permits specify conditions for lopping slash to enhance decomposition and reduce fire hazards.. The penalty for cutting unmarked trees is set at three times the value of the tree. Utilization standards are specified in each permit in order to limit slash. There are also specifications to limit damage to residual trees and soils, especially in the felling and removal of forest products. Locations for logging roads and landings are determined by the forester; the permit specifies the condition in which these areas must be left at the completion of the operation. The permit makes it clear that the logging operation may be suspended due to wet or extremely dry conditions, at the forester's discretion.

5.2.7.4 Harvesting Systems

These specifications limit the size of skidders and other equipment to minimize soil compaction and rutting and to minimize physical damage to residual trees and cultural resources. These specifications may require specific equipment due to the conditions of the lot. For instance, where it is difficult to place straight skid trails, or where dense regeneration is present, the forester may specify that a forwarder must be used and that skidders are not allowed. Where hauling distances to a truck landing are long, but the lot itself requires skidding, the forester may require that both pieces of equipment must be used. DWSP also may require a tracked feller-buncher-processor on lots that have sensitive cultural resources requiring specialized tree removal, on soils that cannot support heavy equipment, or in stands with heavy forest stocking that cannot be thinned properly with standard equipment.

5.2.8 Internal Review of Proposed Harvesting

The key to the proper protection and management of the resources under the care and control of DWSP is the care and expertise of the staff. As the on-the ground implementers of DWSP's land management plans and policies, the foresters' knowledge of, and sensitivity to the various aspects of the watershed management plan have a direct bearing on the ultimate success of the program. It is impossible, however, for any one individual to assimilate all aspects of the diversity of knowledge in the evolving fields of natural and cultural resource management. A secondary key to implementing sensitive management, therefore, is in-house review by specialists in the various key disciplines of study in natural and cultural resources, and effective communication between these specialists and the forest managers.

Within DWSP, these supporting disciplines include wildlife biology, forest planning, water quality and environmental engineering, civil engineering, and cultural resource protection. Experts available outside DWSP include rare species botanists and zoologists (Massachusetts Natural Heritage and Endangered Species Program) and cultural resources specialists (Massachusetts Historic Commission). DWSP also has available a wide variety of experts conducting academic research on the watersheds at any given time, in part because of the research value of the resources under DWSP's care and control. These professionals and interested non-professionals who spend time studying and exploring the watersheds contribute invaluable observations that complement DWSP's understanding of its watershed resources.

To efficiently and effectively coordinate and focus this collective knowledge towards the improved protection of the drinking water supply and other natural and cultural resources, DWSP has developed the following procedure for the annual review of all proposed DWSP forest management activities on the Quabbin Reservoir watershed. These reviews are in addition to the general guidelines for cultural and wildlife resource protection.

- Each December, DWSP's foresters compile a plan of all proposed forest management that could occur during the next fiscal year (July-June). The only operations not included are emergency salvage following natural disturbance events. Each January, the foresters carefully map and describe the boundaries of each planned operation so that they are readily distinguishable on the ground (where boundaries are not easy to describe, they are marked with flagging). These outer boundaries may include internal areas where logging is restricted (vernal pools, stream filter strips, etc).

- Quabbin foresters or Natural Resources staff digitize the maps of the planned operations, which include the location of wetlands and previously identified critical cultural and wildlife sites. The foresters then submit these maps and completed forms describing the proposed silviculture in detail to the DWSP Natural Resources Section. Natural Resources staff prepare area summaries of these operations, and check the overall consistency of the operations with management plan silvicultural and resource protection objectives. These proposals will also identify the subwatersheds intersected by the proposed lots, as well as the proportion of each lot that falls within Zones 1, 2, and/or 3. Natural Resources staff will compare the proposed subwatershed and zone coverage to target objectives for the year and for the decade. After Natural Resources staff have reviewed the proposed operations, the Natural Resources Director then forwards copies to the watershed Regional Director, the DCR archaeologist, and the DWSP wildlife biologist.

- For proposed lots with openings that exceed 2 acres in size, the forester proposing the lot will also detail the relative hydrological sensitivity of the area on which these are proposed as well as the value of the larger openings as early successional habitat that benefits rare and uncommon species and as uncommon forest habitat for more common species. These lots will be reviewed internally on that basis, but prior to being approved, they will also be presented to the general public, for review and comment, at the annual spring public meeting and will also be presented for review and comment to the Quabbin Watershed Advisory Committee.

- From 1986 to 1996, a variety of consultants, in collaboration with Boston University's Department of Archaeology and the Swift River Historical Society compiled cultural resource maps for Division watershed properties (available for review through DWSP Interpretive Services at the Quabbin Visitor Center). These maps denote known and likely historic sites. When forest management is planned for areas containing or likely to contain cultural resources, the DCR archaeologist identifies types of activity that could damage these resources, such as soil compaction or disruption of existing structures such as walls or foundations. The Archaeologist may also make recommendations for removing trees that threaten existing historic structures, and identifies areas of high, moderate, or low probability of containing prehistoric occupation sites. With these concerns in hand, the foresters modify timber-harvesting approaches as needed to protect these resources.

- Each spring, DWSP's wildlife biologist reviews the planned forest management operations. Where necessary, the wildlife biologist conducts site examinations. Landscape level wildlife changes over long time spans will also be tracked using an evolving set of techniques. Local knowledge of state rare, endangered, and threatened species is referenced, as well as the location of any critical or important habitat features in the wildlife biologist's files. After completion of fieldwork by the wildlife biologist, the foresters are alerted to any potential conflicts between the proposed work and important habitat features, keyed to flagging on the ground where necessary. Specific wildlife Conservation Management Practices are outlined in Section 5.4.3 of this plan.

- Each spring, DWSP's Environmental Quality staff reviews the planned forest management and, where necessary, conducts site examinations. The Environmental Quality staff may give site-specific guidelines regarding special precautions designed to increase the protection of site water quality.

- In 1995 and 1996, the Division contracted with a professional botanist to review all proposed harvesting lots for the presence of rare or endangered plant species. The bulk of this plant inventory occurred during May and June, although the botanist made preliminary recommendations pending an additional survey for late flowering species, conducted in August, for a limited number of these operations. In the final reports, the botanist made specific conservation management recommendations to protect these plant populations.

- Where the review process identifies undesirable potential impacts, the foresters consult with the reviewers to design a practical solution. If there are any changes in the area to be harvested and/or in the proposed practices, the forester is responsible for notifying the Natural Resources Section in order to determine if further review is required by the changes. Once the review process is complete, the foresters lay out and mark the harvesting lots. At this time a Forest Cutting Practices Act (MGL Ch. 132) Cutting Plan is prepared (outlining skid roads and specific site impacts), which the logger is required to follow. The Forest Cutting Plan is submitted to the DCR Bureau of Forestry and copied to the local Conservation Commission.

- After the lot has been advertised and awarded to a private timber harvester, Chapter 132 requires DCR Bureau of Forestry staff to conduct a site visit prior to the start of the operation if wetland resources are involved. These regulations also require that DCR Service Foresters check all cutting plans against the Natural Heritage maps of rare and endangered species habitats and, if they overlap, submit these plans to Natural Heritage for review and comment. Training sessions were held in 2004 to enhance the relationship between DCR foresters and the Natural Heritage staff (which remains overburdened with review responsibilities), and an Interagency Service Agreement is being completed to enable improvements in this critical collaboration.

Throughout the active operation, it is the responsibility of the forester in charge to continuously monitor compliance with water quality protection measures, including: stream crossings and work near wetlands; conditions of skidder and forwarder roads as well as main access roads; equipment maintenance; and the treatment and placement of slash. The DWSP "Permit to Harvest Forest Products" includes detailed specifications for each harvesting operation. During the operation, DWSP reserves the right to suspend the harvesting activity if warranted by weather, soil, or wildlife conditions. Upon completion of silvicultural operations, it is the responsibility of the foresters to check for full compliance with all timber harvest permit specifications prior to the release of the performance bond and filing of final reports.

A separate review process is required for proposed access road development or the opening of new gravel operations. See Section 5.3.6.6., page 198 for details of this process.

5.2.9 Post-harvesting Monitoring and Reporting

All active timber harvesting is regularly monitored by DWSP field foresters to assure compliance with both state regulations and DWSP policies for the protection of natural and cultural resources. Immediately following the completion of a timber harvesting operation, the treated area is carefully reviewed in the field by the responsible DWSP forester to assess the operator's adherence to Conservation Management Practices and other requirements of the harvesting permit. This includes a review of the operator's protection of the residual forest, soils, wetlands, and identified special habitats or plant populations, as well as the proper post-harvest treatment of access roads (back blading and the installation of water bars to divert water on steep sections), stream crossings (removal of temporary bridging materials and smoothing of approaches), and landings (removal of unutilized materials, smoothing, seeding if necessary). The Division holds a performance bond on all harvesting contractors and the return of this bond is contingent on the operator's compliance with all permit requirements.

In addition to post-harvest monitoring of operator compliance, timber sale areas are monitored for the silvicultural success of the operation. In areas expected to regenerate, regeneration surveys are conducted 3-5 years following the treatment, to assess the density and diversity of the understory response. The most common method used by the Division is to collect tree, shrub, and herbaceous information within small circular plots along transects, to determine both the success of the tree regeneration and possible competition presented by both native and alien, invasive plants. Browsing surveys are also conducted in these areas to monitor the effects of deer and moose on the forest's regeneration. Rare plant populations and wildlife utilization of unusual habitats (e.g., vernal pools) are monitored both before and following the harvest, to determine positive or negative effects.

5.2.10 Annual Reporting of Implementation Results

In advance of the annual public meeting to present progress on the plan (see Section 1.7.3), Foresters and Natural Resources Staff prepare an annual report that includes a listing of the timber sales conducted and the acres treated, a detailed description of wildlife management activities, and reports from new or ongoing research and monitoring efforts. These reports are presented to the public at the annual meeting, at which public comment is also sought for any proposed refinements or modifications to the 10-year land management plan. While it is the intent of the Division to regularly update the plan to incorporate new information either from internal monitoring efforts or from outside research, these proposed changes will only be incorporated after public review and comment have been sought through the annual meeting or a similar type of well-advertised public meeting.

5.3 Management of Other DWSP Lands

DWSP staff manages the non-forested DWSP-controlled lands in the Quabbin Reservoir's watershed system on a case-by-case basis. Presently, four non-forested areas are exceptions within the Land Management Program. These areas are non-forested lands that: 1) fall within administration areas; 2) are dedicated to the limited fishing program; 3) serve as viewsheds; or 4) are outside of the watershed itself (some parts of Quabbin Park including Quabbin Cemetery). Collectively these areas are managed in the context of the drinking water supply's watershed, but unique attributes require tailored land management approaches. The management of these other DWSP lands is briefly discussed below.

Highlights of Management of Other DWSP Lands:

1. Grounds around administration areas and the fishing areas are maintained to meet recreation and aesthetic objectives, while also addressing water supply protection issues.
2. Open lands include fields, powerline rights-of-way, gravel pits, and others total about 1,000 acres at Quabbin and are maintained for a variety of purposes.
3. 5 high use viewsheds are kept open to allow exceptional vantage points from which to view the watershed.
4. Areas within the Quabbin Park that are maintained for recreation or public access include the Visitor Center, Winsor Dam, Hank's Meadow and Goodnough Dike picnic areas, and the Quabbin Park Cemetery.
5. Access roads are critical to the security and management of the watershed lands and associated structures. Roads are categorized by width, surface material, drainage characteristics, and hydrologic sensitivity. CMPs for road maintenance and the process for spill response are detailed, as well as the internal review process for roadwork and gravel extraction.

5.3.1 Grounds around Administration Areas

The DWSP Administrative Areas are located near the Winsor Dam in Belchertown, MA. The area includes the grounds around the main Administration Building which holds the Quabbin Visitor's Center, the MA State Police Barracks, the hangar/boat launch, and staff offices. In addition, behind the Administration Building, there are garages for vehicles and engine repair and the Stewardship Forest. Nearby, in the area of the Emergency Overflow near Bluemeadow Road there are several houses serving as offices for forestry and natural resources staff and watershed rangers. Equipment and material storage is located in these restricted use areas. This area includes a large, visitor parking area typically used by cars, but also by tour buses on a seasonal basis.

5.3.2 Boat Launch Areas 1, 2 & 3

Boat Launch Area 3

Boat launch areas 1, 2 & 3 are high use recreational areas within DWSP lands in the Quabbin Reservoir Watershed system. The number of visitors to these areas is recorded; **Table 50** shows the numbers for the 2006 fishing season, when the areas were open 5 days per week. DWSP manages these areas to reduce the risks from sanitation facilities, gas and oil, aquatic plants, non-point source pollution (from vehicle parking and boat launching), and hazardous material storage (e.g., fuel for boats). Monitoring and rule enforcement is conducted by Watershed Rangers and the fishing area attendants with support from the Massachusetts State Police and Massachusetts Environmental Police Officers. DWSP staff use the Watershed Protection Regulations, 350 CMR 11.00 as well as the Division's Public Access Management Plan to guide specific management decisions in these areas.

Table 50: Boat Launch Areas - Recorded Visitors during 2006 Season

Visitor Type	Area 1 (Gate 8)	Area 2 (Gate 31)	Area 3 (Gate 43)	Totals
Shore Fishing	1,382	547	979	2,908
Private Boats	4,270	5,859	6,073	16,202
DCR Rental Boats	2,952	2,291	2,972	8,215
Fishing Licenses Sold	764	663	725	2,152

5.3.3 Maintained Open Land

Approximately 1,000 acres of open land has been created and maintained within the Division's holdings at Quabbin, either as part of an historic cultural landscape (Dana Common or Prescott Center), as openings surrounding administration areas (around buildings, Winsor Dam, Goodnough Dike, Quabbin Tower, and Hank's Meadow in Quabbin Park; around Shaft 12; fishing areas, etc.) or for wildlife habitat (open fields in Gates 12, 17, 20, 29, 45). The most recent comprehensive forest typing identified the open areas and acreages shown in **Table 51.** These areas are maintained through regular mowing or less frequent brush-mowing and/or prescribed fire.

Table 51: Maintained Open Lands at Quabbin

Type	Description	Acres
Abandoned orchard	Areas with planted fruit trees that persist despite competition, some of which are actively maintained for wildlife or ornamental purposes	8
Grass or herb cover	Land that is maintained in grasses or herbaceous cover but not associated with administrative areas	311
Upland brush	Recently abandoned fields in a wide mix of mostly brushy cover; some are maintained via occasional mowing	111
Power lines	These areas are kept open by power companies and other utilities and serve incidentally as wildlife habitat	289
Administration areas	This category includes the footprint of buildings, parking lots, and other structures, as well as mowed fields and grounds surrounding these	154
Lawns, ornamental plantings	Areas around administrative buildings within Quabbin Park, on and adjacent to dams and dikes. Dominated by mowed grass and ornamental plantings	88
Gravel pits	Areas from which gravel is currently or has been historically extracted and are not currently forested	17
TOTAL		**978**

Enfield lookout

5.3.4 Viewsheds

A viewshed is an area of land, water, or combined landscape that is visible from a fixed vantage point. The term is used widely in urban planning, archaeology, and military science. In DWSP's land management context, viewsheds are vantage points of particular scenic or historic value in the watershed that are deemed worthy of preservation. The preservation and creation of viewsheds is a secondary goal in DWSP's land management decisions and requires both forest harvesting decisions (to maintain the view) and the designation and maintenance of open space areas.

Examples of DWSP viewsheds within the Quabbin Reservoir watershed system include:

- Pelham Lookout - magnificent view of the west arm of the reservoir and Prescott Peninsula.
- New Salem Lookout - magnificent view of the north end of the reservoir and forested lands.
- Enfield Lookout - magnificent view of the reservoir's west and east arms.
- Quabbin Hill Lookout Tower – view of Mount Greylock and New Hampshire on a clear day.
- Frank E. Winsor Memorial Lookout – direct view of the Winsor Dam.

5.3.5 Quabbin Park Recreation Areas

Quabbin Park (which includes the 82 acre Quabbin Cemetery) is approximately 3,000 acres in size. The Park represents nearly 4% of the DWSP owned land in the Quabbin Reservoir Watershed system. Estimates suggest that over 80% of the recreational use in the system occurs in this 4% of the system, half of which is off the watershed. One half of the Park is located on watershed lands, and the other half, primarily the cemetery, is located on off-watershed lands.

There are many areas within the Park used by the public for passive and active recreation access, including:

- Quabbin Visitor's Center (and restrooms) located in the Administration Building.
- Winsor Dam located near the Administration building used for walking and biking. Since September 11, 2001, the Winsor Dam has been closed to general vehicle access.
- Y-Pool (Seasonal Portable Toilet) located off-watershed used for fly-fishing.
- Winsor Memorial used for bird watching, sightseeing, and picnicking.
- Quabbin Hill Lookout Tower (Restrooms and Portable Toilets) used for sightseeing, bird watching, and picnicking.
- Enfield Lookout (Portable Toilet) birding, walking, and picnicking.
- Hank's Meadow/Picnic area (seasonal Portable Toilet) used for bird watching, hiking, and picnicking.
- Goodnough Dike/Picnic area (seasonal Portable Toilet) used for walking, biking, bird watching, and picnicking.
- Quabbin Park Cemetery is approximately 82 acres in size. It contains over 6,000 graves that were relocated from the towns of Greenwich, Prescott, Dana, and Enfield.

5.3.6 Access Roads

DWSP Quabbin watershed lands include a woods road system of approximately 200-225 miles that provides vehicle access throughout most of the watershed area (some roads are being closed and allowed to return to forest cover; some occur within power line rights-of-way). The majority of these roads date to the pre-reservoir communities that were settled in this area. Some of these were well-constructed, well-drained roads that have been maintained by DWSP to varying degrees depending on priority for their usage. Others were created as simple cart paths and have since evolved to carry heavier traffic, but may not have been well-designed or placed for that purpose. At an average width of ten feet, the 200+ miles of Quabbin woods roads cover an estimated 242 acres of DWSP lands on the Quabbin watershed.

The Quabbin woods road system is essential in order to gain access for key watershed management activities including fire protection, forest management, and police patrols. The interface between roads and water resources is frequently the most likely source of water supply degradation on an otherwise stable, forested watershed. The proper maintenance of woods roads controls the deposition of sediment and organic matter into nearby tributaries, and is among the most critical land management practices conducted by the Division.

5.3.6.1 Road Categories

Quabbin's woods roads have been categorized into four types, listed in **Table 52**.

Table 52: Road Categories in the Quabbin Reservoir Watershed

Type	Road Width	Road Surface	Drainage	Maintenance Considerations	Example
Type 1: All Weather Gravel or Asphalt Roads	12 ft.-24 ft	Processed gravel or pavement	System adequate to protect roadway in most climatic conditions (50 year storm)	Type 1 roads that have a pavement surface will be swept clear of the build up of organic materials every five years. Type 1 gravel roadways will be graded annually with a road grader. Ditches and culverts will be cleared and culverts replaced as necessary. Roadside brush will be mowed yearly.	Pavement – Gate 40 road to Dana; Gravel – Gate 20 road to Lily Pond
Type 2: Secondary Gravel Roads	10 ft. - 12ft.	Processed gravel or bank run gravel	System adequate to protect roadway throughout most of the year. Most Type 2 roads will be closed during the spring mud season.	Type 2 Roads will be graded annually with a road grader. Ditches and culverts will be cleaned and kept free of debris and culverts will be replaced as necessary. Roadside brush will be mowed a minimum of once every three years	Governor's Woods Road from Gate 8 to Reservoir.
Type 3: Intermittent-use Roadways	8 ft.-12 ft.	Gravel or grass covered	System inadequate for use except when conditions are very dry.	Many of these are dead-end access roads not more than 1/2 mile in length. These roads will be mowed every three years to keep them open. Any culverts that are present, particularly at brook crossings, are inspected and maintained as necessary. Some of these roadways are situated on hillsides with a greater than 10 degree slope. Special consideration must be exercised to protect the vegetative cover and to maintain culverts and water bars on these slopes.	Gates 24 and 25 to the intersection of Gate 22 road
Type 4: Forwarder Roads	8 ft.-12ft.	Vegetative cover, impassable in all seasons except by specialized machinery	Temporary drainage systems may be used. Waterbars are used to control erosion on slopes	These dead end access roads are used only on a frequency of every five to forty years. These roadways are only used during the actual operation of timber sales; when the particular sale is finished the roadway will be stabilized to prevent overland erosion.	

A Special Category is designated for Tractor Trailer Access Roads. These roads generally include all Type 1 Roads, many of the Type 2 Roads, and some of the Type 3 Roads. They are usable by heavy equipment such as tractor trailers, which are the key design vehicle (wheel base of 50 feet chosen for design). Special considerations must be given to the maneuverability of the trailers accessing these roads; trucks must have the ability to turn around or seek other means of egress, to gain traction on steep grades, and to maneuver curves within the vehicle's tracking limits. These roads typically serve as a principal access point for very large blocks of land and therefore must be designed to accommodate a concentrated and higher volume of truck traffic with heavier loads than might be expected of roads designed for standard tri-axle logging trucks accessing smaller areas.

Examples of a Tractor Trailer Access Road include Gate 17, used to access Prescott Peninsula, and East Street from Gate 49 to the truck turnaround located on the Hardwick shoreline. The following minimum design standards shall apply to roads identified to serve as principal collectors of tractor trailer traffic.

Travel Lane Width:	11'6"
Drainage:	Crowned with ditches and relief culverts
Road Surface:	12 inches of processed gravel
Grade Limitations:	Up to 12%
Curve Radius:	41 feet (centerline)*
Curve Widening:	27 feet for 90° deflection*
Turnaround:	80 ft wide by 50 ft deep
Winter Maintenance:	Plowing/sanding specs required as part of logging permit

DWSP recognizes that the differences between standard tri-axle logging trucks and trailers may extend beyond simple physical dimensions. As tractor trailer loads are frequently 'back-hauls' of logs by French Canadian drivers, their may be language barriers as well as a lack of familiarity with the Quabbin woods road system. The Division is beginning attempts to reduce these differences through improved road signage, including identification of critical resources areas like stream crossings and the inclusion of additional site access maps in timber harvesting permits. An improved knowledge of the road system will serve to improve traffic safety and spill response capabilities.

The amount of maintenance needed on each type of roadway is difficult to predict, but is dependent on the response to weather conditions, the seasonal stability of the road, and the level of use. Site characteristics such as topography, landscape position, or proximity to wetlands also factor into maintenance requirements. The work needed to keep all major roads open throughout the year is largely dependent on the weather, and the ability to complete this work is largely dependent on the availability of labor and equipment. Major storm events affect roadways as trees or limbs fall into the roadway making them impassable. Crews are dispatched after major storm events to clear roads of fallen debris. Washouts due to culvert failure or clogged drainage ditches occasionally occur after major storms, although the Division is working to inventory and replace culverts that are undersized or have deteriorated.

DWSP is in the process of identifying specific sections of roads that will need grading work, such as the addition of bank run and processed gravel, in the next ten years. Other general road maintenance occurring on a regular basis includes annual grading of some heavily-used roads, removal of hazardous roadside trees, roadside mowing (which facilitates drainage and keeps roads open), culvert replacement and the processing and spreading of gravel as needed to maintain access or for specific land management activities.

* AASHTO, 2001. "A Policy on Geometric Design of Highways and Streets"

5.3.6.2 Criteria for Determining Hydrologic Road Sensitivity

Some of the roads the Division inherited at Quabbin were poorly located or poorly designed for handling modern log truck or tractor-trailer traffic. The Division is in the process of assessing these roads to determine which can be upgraded at reasonable expense and which are too costly to upgrade. The latter will not be maintained for truck use; the land areas that they access will either be managed by requiring that the wood be forwarded to better roads or will become inaccessible, non-management areas. The criteria currently under development for making this determination include:

1. **Dead-end roads.** Unless a turn-around of sufficient size can be developed without presenting unacceptable risk to water supplies, a dead-end road may not be useable. These roads also present challenges in managing spills, as it can be difficult to maneuver spill response equipment to the site. The filling of Quabbin Reservoir created short spur roads that dead-end at the Reservoir; however many of these have good conditions for creating truck turn-a-rounds.

2. **Grades greater than 10-12%.** Roads with grades in excess of 10-12% can present hauling difficulties for fully loaded log trucks or tractor-trailers.

3. **Physical road limitations.** In some cases, the condition of the road surface (e.g., shallow to bedrock), the absence of opportunities to move water off the road surface (for historic roads that were built or have eroded deep below the surrounding land), poor culverts that are excessively expensive to upgrade to handle a 50-year storm event, and other conditions make the road too expensive to recover to useable condition.

4. **Bridges.** If it is not known whether existing bridges are rated to at least 80,000 pounds, they are considered impassable for log trucks or tractor-trailers.

5. **Hydrologic sensitivity.** This criterion includes the hydrologic distance to the nearest intake, the hydrologic distance to the Reservoir, and the hydrologic distance to any water resource (tributaries, wetlands). The Division is still developing specific thresholds for these considerations.

6. **Critical habitats.** An assessment will be made to determine if reconditioning a road would have unacceptable impacts on critical habitats for flora or fauna. In most cases, the road has been a feature on the landscape for a long time, so that upgrading it is unlikely to cause critical additional impact. There are exceptions to this rule, especially where an upgrade would require major modifications or the addition of a turnaround near a critical habitat.

7. **Cultural/historical resource limitations.** Similar to the critical habitats criterion, the necessary road or site work to upgrade the use of the road might cause unacceptable impacts on cultural resources that have been identified in the area.

5.3.6.3 Regular Review of Access Road Maintenance Needs

The scheduling of road maintenance to coincide with the use of these roads for forest management is a difficult challenge that requires regular communication across several staff groups. Foresters propose silvicultural operations in each of the management blocks on an annual basis based on priorities in the land management plan, current markets for different species and products, and opportunities for improvements in structural diversity and species composition. A component of these proposals is the identification of access needs, which generally include maintenance or upgrades in the haul roads used to remove wood products from the landing to the main highways outside the property and in the landings themselves, in order to accommodate the anticipated equipment and truck traffic. While these proposals give the road maintenance staff an expectation of anticipated work, the scheduling of this work is complicated by the variable time required to complete the marking and selling of the proposed lots and by

the fact that the buyer is allowed to postpone starting a lot for up to two years. Therefore, regular review of priorities for access maintenance and improvement work is necessary.

The Forestry staff holds meetings every 4-8 weeks to review the status of active and pending silvicultural work, markets, changes in regulations, current problems with insects and diseases, and a wide variety of other topics. The Chief Forester will communicate identified current priorities for access work to the maintenance staff following these meetings. In addition, representatives of these two staff groups will conduct meetings in April and August to update the access maintenance priorities. While a variety of variables make it difficult to produce a fixed maintenance schedule, improved, regular communications are designed to better align priorities with availability of maintenance staff and equipment.

5.3.6.4 Pre-Planned Spill Response for Silvicultural Operations

All logging contractors who work on Division properties are licensed Massachusetts Timber Harvesters, with basic training, experience, and a good understanding of the potential threat to water supply represented by the size and weight of their equipment and by the volumes of petroleum products carried on this equipment. Log trucks and tractor-trailers typically carry up to 200 gallons of diesel fuel. Larger mechanized harvesting equipment can carry as much as 150 gallons of hydraulic fluid, as well as diesel fuel. In some situations, the Division allows fuel trucks with much larger capacities to be brought into staging areas to refuel equipment. On operations using hand felling or chainsaw bucking at the landing, chainsaw gas and bar and chain oil will also be on site, though generally in amounts of less than 10 gallons.

The most common type of spill that occurs at harvesting operations is the failure of a hydraulic line on such equipment as feller-buncher-processors or forwarders. While these machines may carry as much as 150 gallons of hydraulic fluid, the failure of one of these high-pressure hoses triggers machine responses designed to prevent high-volume spills, including automatic shutdown of hydraulic pumps or an automatic reversal to pull fluid back into the reservoir. When a spill occurs due to a failed hydraulic line, it typically results in the loss of less than 10 gallons of fluid.

All Timber Harvesting Permits on Division properties require that each piece of logging equipment carry on-board, at all times, sufficient oil-absorbent cloth to catch a ten-gallon spill, providing an immediate response to a leak or a hose failure. In addition, prior to the advertisement of a timber harvesting sale, the Division assesses the area and develops a Spill Response Plan (SRP). Where the lot can be accessed from more than one road, or from both directions on the same road, it is assumed that a spill response could be mobilized quickly from the nearest office (Belchertown or New Salem). However, if it is possible that equipment or trucks could prevent downstream access to a spill (e.g., when the only access road dead-ends at the Reservoir), a box containing oil-absorbent cloths and booms (to stretch across streams or outlets) is placed near the bottom of the access road, as well as a small boat, if required to place an oil-absorbing boom. Finally, a Spill Response Plan is included in the contract for the timber sale, which includes:

1. Locations of all wetlands, streams, culverts, and other water features within the lot.
2. A map showing access to and from the nearest public road, with the location of all wetlands, streams, culverts, intersecting roads, and areas of critical habitat identified.
3. Any limitations placed on the quantity and type of fueling permitted within the lot.
4. The requirement for a pre-harvesting meeting between Division foresters and the logging contractor to review spill response procedures.
5. Locations of permanent and temporary access roads and all staging areas.
6. Locations of spill response boxes, if these are being kept on the lot.
7. A list of phone numbers to call and procedures to follow in the event of a spill.

5.3.6.5 Conservation Management Practices for Road Maintenance

The objectives of forest road maintenance on the watershed are to provide for vehicle access to support key watershed management activities, and to minimize adverse water quality impacts associated with this road system. Activities that are dependent upon a good access road system include fire protection, forest management, and police patrols. These activities require stable, properly shaped and ditched road surfaces with adequate structures to manage storm event runoff. The vast majority of road maintenance on DWSP properties is accomplished by DWSP staff and equipment.

To accomplish these objectives DWSP crews use various mitigating procedures to protect stream water quality during routine maintenance activities. It should be noted that specific sites may require special systems not described here, such as the use of geotextiles, erosion control blankets, subsurface drainage, and rip-rap materials.

- **Shaping Road Surface.** The most basic component of a stable road is proper crowning and ditching, which allow storm runoff to leave the travel surface and be collected in the roadside ditch.

- **Relief Ditches, Relief Culverts, and Waterbars.** The frequent removal of storm water runoff from the roadside ditch is important to limit the amount of soil and gravel that is washed from an area during an event. The spacing of the relief structures is determined by combining site data such as slope of the road, slope of adjacent woodland, soil type and depth, and physical structure of the road. The general rule of thumb is to place relief structures as often as the landscape allows on most slopes. Relief structures, wherever possible, will discharge the storm runoff not less than 50 feet from streams or wetlands.

- **Sediment Traps.** These small basins will be installed where needed as part of road reconstruction activities to reduce the velocity of stormwater and to drop out larger sediments. The traps are formed by excavating a shallow depression or by placing an earthen or stone berm across a low area or swale. The traps are sized based on a target storage volume of 67 cubic yards per each acre of road drainage area. It is recommended that the sediment collected inside of the trap be removed when it has accumulated to one-half the design depth.

- **Dry Season Work.** All road work, except for emergency repair work, some major bridge work (which may extend beyond dry periods), and emergency culvert replacement, will be accomplished during dry periods (primarily summer), when low water flow and stable soil conditions will help mitigate impacts from soil disruption.

- **Use of Silt Fence/Hay Bales.** Wetlands will be protected by properly installed hay bales or industry standard silt fence whenever road maintenance work requires disturbance near these resources.

- **Seeding of Disturbed Areas.** Areas of disturbed soil will be graded and seeded with quick-growing grass species upon completion of road maintenance projects. DWSP has purchased a "hydro-seeder" for this purpose.

- **Special Road Surfaces.** Alternative road surface materials may be appropriate in limiting loss of material through erosion because of the huge variation of historical forest road construction and use. Forest roads that are rarely used may be shaped and seeded with grass. These roads would then be maintained by yearly mowing and culvert cleaning. Depending on location and use, these roads may also be blocked by use of barways to keep out all but essential traffic.

- **Stream Crossings.** It is DWSP's intention to limit catastrophic washouts by replacing under-

sized culverts with structures that will meet standards for a 50-year flood. Both culverts and ditches will be kept open and clear of all restrictions in order to prevent the back up of storm runoff and the resulting washout. In addition, DWSP will continue installation of overflow spill areas (reinforced, low areas on a road adjacent to major streams) capable of spilling the flow from a 100 year flood on major tributaries. Replacement culverts will also be chosen and designed to meet recently revised requirements for the protection of fisheries and other wildlife use of streams. The Division will design replacement stream crossings on fish-bearing, perennial streams and/or where critical habitat has been identified consistent with the fish-passage standards established under the Massachusetts Riverways Program, Massachusetts River and Stream Crossing Standards dated August 6, 2004. It is the DWSP's intent to design replacement stream crossings to the following standards:

- Crossing width should be a minimum of 1.2 times bankfull width.
- Culvert pipes should ideally be embedded to a minimum depth of one foot and a low-flow channel should be shaped within the passage.
- Work should be limited to the period from July 15 to October 1.
- Barriers to fish/aquatic life passage should be eliminated or avoided by:
  - Eliminating inlet/outlet drops
  - Avoiding constriction of flow and/or causing significant turbulence
  - Minimizing tailwater armoring.

5.3.6.6 Internal Review of Proposed Roadwork or Gravel Operations

Much of the roadwork conducted on the watershed is routine and of a maintenance nature. Occasionally, however, new access roads are constructed or raised to higher standards to accommodate more intensive use, or new sources of gravel are developed to accomplish road work. In these cases, since the operations may result in habitat changes and possible impacts on water quality, wildlife, or cultural resources, the following procedure will be followed:

Quabbin woods road

- Development of a plan showing the location to be affected, time sequence of removals and procedures to be employed.

- Consultation with DWSP Section Regional Directors, Natural Resources, Environmental Quality, and the DCR Archaeologist to determine that no significant impacts will occur to water quality, wildlife, or cultural resources.

- Consultation with and completion of all necessary approvals from the Department of Environmental Protection, the Department of Fish and Game, Division of Fisheries and Wildlife (for information on both fisheries and rare species impacts), the local town Conservation Commission, and any other governmental entity with jurisdiction over the chosen site.

- Final approval from the Director of Natural Resources.

5.3.6.7 Beaver Populations in Long-term Planning for Access

Beaver populations in the state (and throughout the Northeast) continue to increase as the number of trappers and amount of human-caused mortality remain low. DWSP constantly deals with plugging of road culverts by beaver. In some situations, DWSP has successfully installed fences and water level control devices. These solutions, however, require continual maintenance and do not offer permanent relief. Further, fencing and/or water-level control devices may not be useful in all problem situations on the watersheds. Based on research in New York State, only 3% of sites are suitable for water-level control devices (Jensen et al., 1999). In situations where water level control devices are not an option, DWSP removes beaver either by trapping or shooting individual animals. Although this solution may offer immediate relief, the habitat and conditions that attracted beaver initially have not been altered and these sites are often re-colonized within a short period of time. DWSP recognizes the limitations of these various techniques and is working to develop a long-term plan for beaver management along roads.

Recent research suggests several management techniques to protect against beaver plugging of culverts. In 81% of sites examined in New York State, culvert size (area of inlet opening) was the major determinant of whether beaver plugged the pipe. The probability of a culvert being plugged increased with decreased culvert inlet opening area. Culverts with just 8 ft^2 of area were plugged 73% of the time, while culverts with 113 ft^2 of area were only plugged 7% of the time. The design of the culvert was also an important determinant of whether beaver altered the site. Pipe-arch culverts were less prone to being plugged by beaver than round culverts. Round culverts are more likely to channel the water and reduce the stream width, alter flow rates, and generate noise that attracts beaver. Unplugged pipe-arch culverts tended to retain the natural stream width. The width of the stream at plugged culverts was twice that of the culvert inlet opening (Jensen et al., 1999).

Both research and general observations suggest that beaver are more likely to occupy sites with lower gradient and smaller width streams (e.g., first or second order), as well as abundant woody vegetation. In areas with flat topography, the total amount of woody vegetation was the primary predictor of beaver presence in New York State (Jensen et al., 1999). Because each site can be evaluated for potential beaver habitat and the probability of culvert plugging, DWSP will incorporate beaver considerations in choosing stream crossing methods. In addition to evaluating watershed area, road classification, and stream size and gradient, DWSP personnel will also consider potential beaver habitat during replacement or installations of culverts. Culverts that may already be experiencing chronic beaver plugging will be prioritized for upgrading or replacement.

5.3.6.8 Management Guidelines for Beaver at Road Stream Crossings

DWSP will incorporate beaver management considerations into road and culvert planning when possible to reduce the probability of culverts being plugged by beavers. Recommended practices include the following:

- Replace existing smaller culvert pipes with larger, oversized pipes, where feasible and applicable.
- Use box or pipe-arch culverts, when possible, with a minimum inlet opening area of 18 ft^2 (smaller sizes are easily plugged).
- Size the culvert so that that the width of inlet is at least equal to or greater than the width of the stream. This will decrease noise and minimize the potential for altering flow.
- Avoid creating a depression or pond at the inlet when installing culverts, as these are attractive to beaver.

- Do not install multiple smaller pipes at a site instead of a larger pipe. It is not a workable alternative, as smaller pipes are much more likely to be plugged.

- Utilize other management options, as needed in situations where beaver have a history of plugging even large culverts (see section 5.4.4.1).

5.4 Wildlife Management

5.4.1 Assessment of Impacts of Planned Watershed Management Activities

The management activities described in this plan will have various impacts on the wildlife community at Quabbin. Most impacts on the wildlife community will be a result of habitat changes or modifications. The forest management approach described in this plan has landscape level affects, although individual changes at any given time will be very localized and small. While the management techniques used to reach the forest management goals will not be as dramatic as historic events (1938 hurricane, flooding of the reservoir), it is important to understand how these plans will affect the habitat and wildlife communities on the watershed.

The Division's primary long-term forest management goal is to establish and/or maintain a forest cover of diverse native tree species of many different age classes on a majority of its land holdings. This goal will primarily be accomplished through uneven-aged forest management. A 20-30 year cutting cycle will be used in most areas, and harvest will be through selection of individual trees or small groups (1/20-1/4 up to 2 acres). Uneven-aged management is the best technique for preserving individual trees of high wildlife value (dens, nests, roost, mast producers) (Payne and Bryant 1994). In addition, uneven-aged management increases vertical diversity. The end result is an even distribution of a low but constant population of understory plants and associated wildlife (Payne and Bryant 1994).

Meeting this primary objective will mean wildlife communities on Division land will be dominated by species adapted to forest conditions. Those species requiring early successional or open habitat will be less common and isolated to those areas where that type of habitat exists. Open and early successional habitat will be maintained on a small percentage of the Division's land, primarily associated with developed areas (dams, dikes), beaver impoundments, and existing fields. Forest wildlife communities should benefit the most from the Division's management plan.

5.4.2 Active Management to Enhance Habitat for Selected Wildlife Species

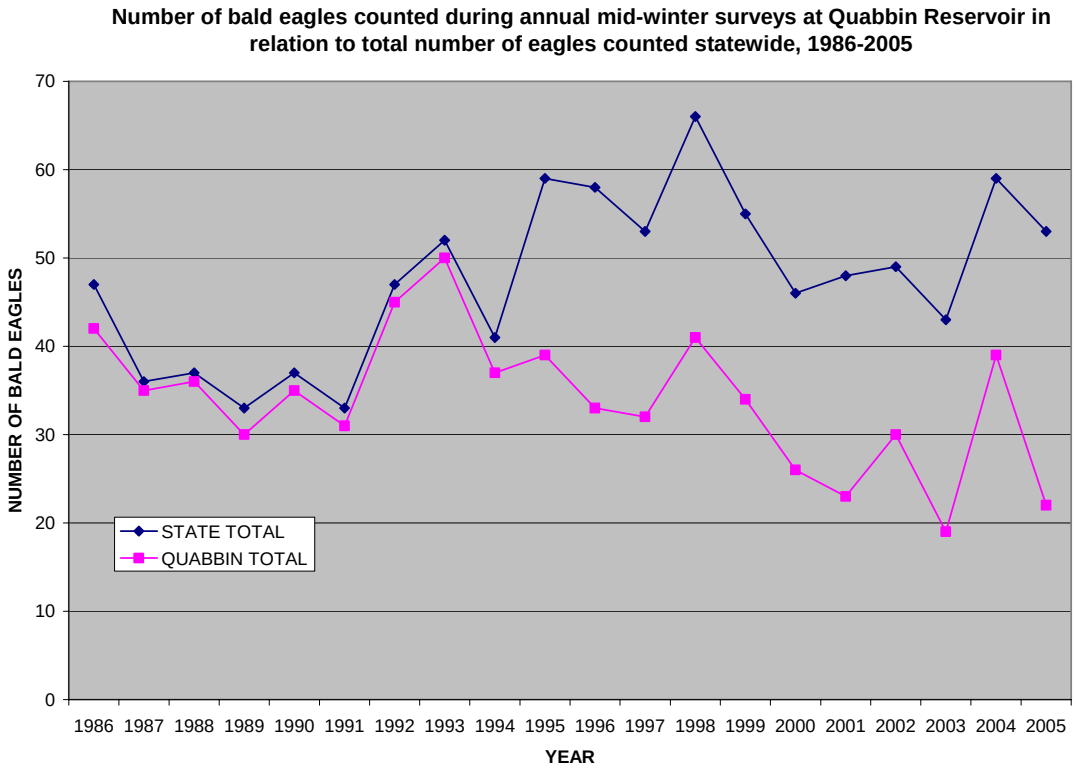
5.4.2.1 Bald Eagles

Quabbin Reservoir has played a critical role in the recovery and continued success of bald eagles in Massachusetts. From 1982 to 1988, 41 bald eagle chicks from Michigan and Canada were transported to Quabbin Reservoir and "hacked" or raised in artificial nesting platforms without human association. The efforts paid off in 1989 when 2 pairs at Quabbin produced the state's first successful breeding efforts. Eagles have bred successfully at Quabbin each year since, and anywhere from 3-5 pairs may breed annually.

Quabbin also serves as a vital wintering area for both resident and non-resident bald eagles. Because of its large size, Quabbin is often the last body of water in the state to freeze, providing open water habitat for eagles well into the winter. Annual mid-winter eagle counts have been conducted in Massachusetts since 1986 along 2 standardized routes (Quabbin Reservoir and Assawompsett Pond). Two additional routes (Connecticut River and Merrimack River) were added in 1995. In the last 20 years, Quabbin reservoir has consistently attracted more wintering eagles than any other area in the state. In fact, the

eagle count at Quabbin has accounted for 41-97% of the total number of eagles seen during the annual survey (**Figure 19**).

Figure 19: Mid-Winter Bald Eagle Counts at Quabbin Reservoir and Statewide, 1986-2005



The bald eagle continues to recover on a national level. In 1995, the Federal status of the bald eagle was changed from Endangered to Threatened. In June of 2007, the Federal government removed the bald eagle from the endangered species list. It still has federal protection through the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act. Its status in Massachusetts remains endangered. As a result, continued effort is made by the Division to ensure its existence at Quabbin. In cooperation with MassWildlife, buoys are placed in the water near active eagle nests to exclude fishermen and boaters from approaching too close. Each spring active nests are visited and eagle chicks are leg-banded, blood is drawn, and overall health is recorded. Leg bands provide critical survival, dispersal, and breeding information.

Finally, special attention is given to shoreline nesting and roosting habitat. When forestry operations are conducted along the reservoir's shoreline, super-canopy trees are selectively saved because these are favored by nesting eagles. In addition, other high quality potential nest trees, particularly hardwood trees with 3-pronged forks or conifer trees with a "bowl" shape near the top are saved. Lastly, consideration is given to thinning around these quality trees to ensure continued growth and allow for easy flight paths in and out of the tree.

5.4.2.2 Common Loons

There is little evidence of nesting loons in Massachusetts during the first half of the 20th century. Between 1940 and 1970 there are sporadic reports of nesting at Quabbin including one report in 1943 and another in 1959. Since 1975, loons have nested annually at Quabbin. Currently, Quabbin hosts the

largest number of breeding pairs of any water body in the state. During the 2005 nesting season, 13 pairs were present on the reservoir; 6 pairs nested, and they produced 10 chicks.

Artificial loon nesting raft

Loons prefer to nest on islands with sandy shores, low-lying vegetation, and a shallow approach that makes it easier to travel to and from the nest. Most loon territories on Quabbin have at least one potential nesting island. However, because Quabbin is a water supply reservoir, its water levels can fluctuate greatly depending on precipitation and consumer use. While loons can tolerate some fluctuation in water levels, increases of more than 6 inches or drops of more than 12 inches typically mean nest flooding or abandonment, respectively. Reservoir water levels cannot be specifically controlled during the loon nesting season. Therefore, in order to overcome potential water level problems, the Division utilizes artificial nesting rafts.

These loon rafts are constructed of dried cedar logs, wire mesh, and a camouflage canopy. Rafts are loaded with vegetation and anchored in the loon's territory each spring. During late summer, rafts are towed to shore, propped up, and stored for the winter. At Quabbin, there are currently 11 rafts in 11 different loon territories. Rafts allow nesting loons to escape fluctuating water levels. While rafts can increase loon productivity, they do not always succeed in attracting the nesting pair. There are several loon pairs at Quabbin that have a raft in their territory that still chose to nest on a natural island.

5.4.2.3 Nest Boxes for Land Birds

Some bird species may lack suitable nesting sites needed for successful breeding. While nest boxes are not a substitute for proper habitat management that provides natural snags and cavity trees, they can provide rare or uncommon species an opportunity to increase its local or regional population. As many as 50 species of North American birds are known to use nest boxes (Payne and Bryant 1994). In particular, bluebirds, kestrels, and a variety of owls respond well to the presence of nest boxes.

There are approximately 20 nest boxes located in early successional non-forested habitat on Quabbin Reservation. The boxes were originally erected to attract breeding bluebirds to the open habitats. However, many boxes need repair or to be replaced. In addition, little effort is made to adequately remove old nesting material, inspect the boxes during nesting season to remove unwanted species, or checked for insect infestations. Efforts will be made to inventory existing boxes, make necessary repairs, and monitor nesting effort during the season. In addition, other nesting boxes may be erected to attract kestrels and/or owls.

5.4.2.4 Snake Hibernacula

There is one known snake hibernaculum on the Reservation located in Hardwick in an old spoil pile that was created when one of the vertical shafts was dug. The spoil pile is essentially a huge mound of rocks and stones that provides small cavities and crevices where snakes can spend the winter. Snakes make their way through the crevices to areas below the frost line. Ideally, hibernacula face south to allow adequate sun exposure. Over time, these spoil piles grow vegetation, including large trees. The vegetation, particularly large conifer trees, can create too much shade and degrade the quality of the site. In order to restore the full potential of the hibernaculum in Hardwick, the Division removed all vegetation from the spoil pile to allow full sunlight to reach the ground. This vegetation removal will be conducted periodically to maintain the habitat.

5.4.3 Conservation Management Practices (CMPs) for Wildlife Management

DWSP foresters are concerned primarily about maintaining water quality standards and improving forest health and vigor. Monetary gain from forest resources is a minor consideration when planning management activities. A direct result of this flexibility is that it allows DWSP foresters to incorporate sound and beneficial wildlife management components into their forest cutting plans. High quality mast trees, active and potential den and nest trees, and critical habitats have been, and continue to be, conserved and encouraged on DWSP property.

CMPs for wildlife management are generally complementary to water quality protection standards. The following wildlife CMPs highlight current management techniques already being practiced and elaborate on other management techniques that can be employed.

5.4.3.1 Habitat Features and Management Recommendations

5.4.3.1.1 Vernal Pools

Management Objective: DWSP will locate and identify all vernal pools on its properties and maintain vernal pool depressions in an undisturbed state.

Recommended Practices - General:

- Seek additional input from NHESP when management activities are going to occur around a pool that contains state-listed species.
- Digitize all aerially interpreted vernal pools and provide data layer to GIS personnel for inclusion in land management activity plans.
- Identify and confirm status of photo-interpreted vernal pools.

Recommended Practices within Pool Depression:

- Continue to maintain physical integrity of pool depression and its ability to seasonally hold water.
- Continue to keep depression free of slash, treetops, and sediment from forestry operations. If slash does fall into pool during the breeding season do not remove it so breeding activity is not disturbed.

Recommended Practices at Edge of Pool:

- Keep shaded condition in 100-foot buffer zone around pool depression.
- Minimize disturbance of forest floor within 200 feet of pool edge.
- Avoid making ruts >6 inches deep within 200 feet of the pool.
- Conduct low-intensity harvests preferably when ground is frozen.

Vernal pools are contained basin depressions with no permanent outlet that typically hold water for at least 2-3 months in the spring and summer. Vernal pools may or may not dry completely each year, but their periodic drying, shallow water, winter freezing, and low oxygen levels keeps them free of fish populations.

Because of their unique characteristics, vernal pools play a critical role in the life cycles of many amphibians, reptiles, and invertebrates. As a result, the Division considers vernal pools to be critical wildlife habitats. In fact, many state-listed species are associated with, or dependent on, vernal pools. Many vernal pools dry completely during the late summer and fall and can be difficult to identify. In recent years, the Division has made efforts to locate and identify vernal pools during the spring. Accurate and detailed records of located pools, including UTM coordinates and animal use, are stored in databases. In addition, the University of Massachusetts, Amherst identified over 500 "potential" vernal pools on the Quabbin watershed through aerial photos. These pool locations have been digitized; field checking to ascertain their status is part of the on-going spring field work. Locations of documented vernal pools will be transferred to a GIS datalayer for inclusion in land management planning documents.

Vernal pool

Research is currently being conducted at Quabbin Reservation to test the effectiveness of Massachusetts Best Management Practices for vernal pools. While the state BMPs provide direct protection of the pool, there is concern that the wildlife species utilizing the pool may also rely on a larger area surrounding the pool for a majority of their life cycle. This research will test the effectiveness of the current BMPs.

5.4.3.1.2 Seeps

Management Objective: DWSP will continue to protect seeps, springs, and surrounding soils.

Recommended Practices:

- Avoid leaving slash in woodland seeps or springs.
- Maintain mast-producing trees above and around seep.
- Remove conifer trees on south side of seep; retain conifers on north and west sides of seep.
- Schedule harvests to occur on frozen ground or during the driest conditions where seeps are present.
- Avoid running heavy equipment within 50 feet of the edge of a seep.
- Use seeps, when feasible, as the center for uncut patches to retain cavity trees, snags, and other wildlife features.
- Lay out skid trails and roads in stands where seeps are present and obvious prior to the harvest.

Winter seep

Woodland seeps tend to be small (< ¼ acre) areas where ground water flows to the surface of the forest floor and saturates the soil. Seeps generally don't freeze during the winter and typically have little or no snow cover. Seeps often occur in natural depressions and may act as "seed traps" in which nuts, seeds, and fruits from surrounding trees and shrubs accumulate. This makes them important winter feeding sites for turkey, deer, and other wildlife.

Seeps provide a seasonally important source of food and water for resident and migratory wildlife (Hobson et al., 1993). These areas tend to have early sources of green vegetation. This can be an important food source for black bears in the spring and early summer. Earthworms and insects at seeps attract early migrants such as robins and woodcock. Spring salamanders and hibernating frogs, which can attract skunks and raccoons, may also use seeps.

5.4.3.1.3 Orchards and Fruit Trees

Management Objective: DWSP will save apple and other fruit trees and increase their health and vigor when feasible.

Recommended Practices:

- Continue to identify abandoned orchards and clusters of fruit trees.
- When trees are being marked for harvest, save, if possible, all fruit trees.
- Remove other trees and shrubs, when feasible, back to the drip line of the apple tree.
- Remove large over-topping trees if the fruit tree is shaded by them on at least 3 sides, particularly to the south.
- Prune and fertilize trees, when possible, at least every 3 years.

Abandoned apple orchards and scattered fruit trees exist on DWSP watershed property. Wild apple trees are one of the most valuable wildlife food species in the Northeast (Elliot 1998, Tubbs et al., 1987, Hobson et al., 1993). White-tailed deer, grouse, squirrels, fox, fisher, porcupine, and rabbits will eat apples or apple seeds. Apple trees also provide nesting and perching habitat for bluebirds, flycatchers, robins, orioles, and sapsuckers (Elliot 1998). Apple trees in abandoned orchards eventually become crowded by invading shrubs and over-topped by the encroaching forest. Prolonged crowding and shading will lead to decreased vigor and eventually death.

Young apples

5.4.3.1.4 Wildlife Wintering Areas

Management Objective: DWSP will maintain the functional value of wildlife wintering areas.

Recommended Practices:

- Identify and map all known or potential WWA using aerial photos, cover type maps, and field inspections.
- Schedule forest harvest operations within WWA, when feasible, during December-April so tree tops are available for browse.
- Protect advanced conifer regeneration during timber harvesting.
- Cut stumps low to encourage vigorous sprouting.
- Planned activities within WWA should be conducted to ensure that at least 50% of the wintering area remains in closed canopy coniferous overstory to provide functional shelter.
- Avoid concentrating harvest in any one area of the WWA.

- Try and maintain travel corridors (unbroken, dense softwood cover 60-100m wide) that connect all areas of the WWA.

Wildlife wintering areas (WWA) provide shelter and food for animals during the winter months when cold temperatures, snow cover, and limited food resources create physiologically demanding conditions. An important wintering area is often related to white-tailed deer use of concentration areas or "yards." These deer wintering areas (DWA) typically are in hemlock or pine stands where there is >70 percent conifer crown closure (Elliot 1998). Deer typically move to these areas when snow depths are around 12" (Flatebo et al., 1999). DWA provide reduced snow depths, higher nighttime temperatures, reduced wind, and greater relative humidity (Flatebo et al., 1999).

These areas must not only provide adequate cover, but also a quality supply of deer food. Cedar, red and sugar maple, birch, and hemlock are preferred foods. Another important wintering area is dense conifer cover (e.g., spruce stands) that provides increased thermal protection and wind cover for a variety of birds and mammals. For example, grouse will seek conifer stands when snow depths are <8 inches for thermal protection.

The general guideline for wildlife wintering areas is to maintain as much overstory as possible, while providing for the establishment and continued growth of preferred browse and conifer tree species.

Wildlife wintering areas

5.4.3.1.5 Mast

Management Objective: DWSP will continue to maintain and encourage a variety of mast-producing plants within the watershed**.**

Recommended Practices:

- Continue to manage stands to contain multiple species of mast-producing trees and shrubs.
- Continue to retain productive beech, oak, and hickory trees when they occur as single or scattered trees in stands dominated by other species.
- Retain beech trees with smooth or blocky bark or raised lesions to promote resistance; remove standing trees with sunken cankers or dead patches to reduce sprouting of diseased individuals. Retain some large beech trees that have potential for good mast production, regardless of disease condition.
- Lay out skid trails and roads that avoid vigorous patches of understory shrubs.
- Save all hardwood mast trees that occur in conifer plantations when practical.

Mast is a critical component of quality wildlife habitat. Trees, shrubs, and vines produce fruits, nuts, and berries called mast. Mast can be hard (nuts, seeds) or soft (fruit, berries). It contains more fat and protein than other plant foods and is actively sought by a variety of birds and mammals. In autumn, mast is particularly important as many animals will focus on eating mast in preparation for winter. Bears, squirrels, raccoons, deer, and turkey will fatten up on acorns, beechnuts, and hickory nuts. Resident songbirds such as nuthatches, chickadees, and bluejays rely on mast during winter when other food is scarce. Migrating birds will often rely on fruits and berries during migratory stops to replenish energy.

Although all trees and shrubs are defined as mast producers, some species are more important to wildlife. The value of mast to wildlife differs with the size, palatability, accessibility, nutritional content, abundance, and production frequency (Flatebo et al., 1999). In general, oak, hickory, beech, walnut, butternut, cherry, ash, and conifers are the most important mast trees. In addition, birch, hazel, alder, and aspen are also important to some wildlife species.

5.4.3.1.5.1 Hard Mast

At the Quabbin, red, white, black, and scarlet oaks are the most important source of mast. Hickories and beech comprise a relatively (< 3%) small component of the overstory. Oaks are probably the most important wildlife mast trees in the northeast. Acorns are eaten by over 100 species of birds and mammals (Healy 1997a). The frequency and characteristics of oak production varies from species to species. Red oaks produce a good crop of acorns every 2-5 years, black oaks every 2-3 years, and white oaks every 4-10 years. Red and black oak acorns take 2 years to develop, while white oaks take only 1 year. Peak acorn production begins at around 25 years for red oaks, 40 years for white oaks, and 40-75 years for black oaks (Flatebo et al., 1999). White oak acorns contain less tannin and may be more palatable to wildlife.

Beech and hickory trees comprise a small component of the Quabbin watershed forest. Hickories are scattered around the watershed and can be locally abundant in some compartments. They are also found along interior roads near former home sites. They have good seed crops every 1-3 years and begin producing quality crops at 40 years. Hickory nuts have one of the highest fat contents of any mast. Beech trees are extremely rare within the watershed, comprising less than 0.5% of the overstory. The prevalence of beech bark disease and low market demand has shifted attention away from this species. However, beechnuts can be an important source of food for a variety of wildlife. Wild turkeys prefer beechnuts to all other mast (Williamson, undated).

The seeds of maples, birches, ashes, and conifers provide food for many birds and small mammals. Red squirrels rely heavily on conifer seeds and their populations will fluctuate in response to annual crops. Birches are an important mast producer because most of the seed crop is retained on the tree above the snow. Birds, including pine siskins and grouse, count on birch seeds for their winter diet. White and red pines are the most widely distributed conifers at Quabbin. Mice, voles, grosbeaks, and finches are a few of the animals that utilize conifer mast. Chickadees and goldfinches prefer hemlock seeds.

Grapes, an example of soft mast

5.4.3.1.5.2 Soft Mast

Black cherry trees comprise a relatively small percentage of the Quabbin watershed forest canopy. However, bears, small mammals, and over 20 bird species eat cherries (Flatebo et al., 1999). Pin and chokecherries are short-lived, but provide valuable fruit to wildlife. A variety of understory shrubs and

trees produce soft mast. Blueberries, serviceberries, dogwoods, and viburnums are abundant. In addition, herbaceous plants such as blackberry, raspberry, wild strawberry, and partridgeberry, are utilized by many species of wildlife, as are grapes.

5.4.3.1.6 Wildlife Trees

Wildlife trees are often divided into two categories: snags and den trees. Snags are standing dead or partially dead trees at least 6" dbh and 20 feet in height. Den trees are live trees possessing a cavity large enough to serve as shelter for birds and mammals or a site to give birth and raise young. In general, den trees must be 15" or greater in dbh and have a minimum cavity opening of 4" in diameter (Blodgett 1985). Over 50 species of northeastern birds and mammals utilize snag and den trees during part of their lives (Blodgett 1985). Some uses of snags and den trees include cavity nest sites, nesting platforms, food cache, dwellings or dens, nesting under bark, overwintering sites, hunting and hawking perches, sources of feeding substrate, and roosting.

Forestry operations most likely have the greatest potential impact on the number, type, and location of snag and den trees at Quabbin. Thinnings, salvage, firewood cutting, and windthrow will result in wildlife tree loss. The Division's use of uneven-aged management, however, is conducive to snag management. Single-tree or group selection harvest practices will have only slight to moderate adverse impacts on snag production and retention. Although it would be ideal to salvage all wildlife trees, practical field applications make that unlikely. It is possible to maintain an optimal number of snags and dens across the watershed (**Table 53**).

Table 53: Optimum Number of Snags/Den Trees per 100 Acres by Habitat Type

	Forest Interior		Semiopen/ open	Wooded Watercourse
Tree dbh (in)	*Dens*	*Snags*	*Dens*[1]	*Dens*[1]
> 19	100	0	300	200
10-19	400	400	400	1400
< 10	200	200	300	900

[1] Animals here need den trees because creating snags by deadening trees is not recommended in these land-use types.
Source: Payne and Bryant, 1994

5.4.3.1.6.1 Snags

Management Objectives: Forestry operations will continue to provide a supply of good to excellent quality snag trees, distributed over time and space in order to maintain self-sustaining populations of all cavity dependent wildlife. In areas where good snag trees are lacking, poorer quality trees should be retained until better trees develop.

Recommended Practices:

- Leave all snags when possible, within 100 feet of wetlands and riparian areas.
- Maintain a minimum of 6 snag trees per acre; 4 should be > 24" dbh and 2 <24" dbh.
- Avoid disturbing snags from April to July to stay away from nesting birds and denning mammals.
- Leave snags in place as coarse woody debris instead of removing them if they are felled during management operations.
- Identify, when possible, current or potential snags through exterior signs such as fungal conks, butt rot, burls, cracks, wounds/scars from lightning, fire, or mechanical damage, woodpecker holes or cavities, or dead or broken limbs or tops so they can be retained.

As a tree dies, it progresses through several stages of decay (**Figure 20**) and is used by different wildlife at each stage. Newly exposed bare branches provide excellent perches for woodland hawks (Cooper's, sharp shinned), as well as flycatchers and phoebes. During the loose bark stage, brown creepers and bats may nest or roost under the bark.

As a tree deteriorates, primary excavators (woodpeckers) begin to create cavities. Almost all northeastern woodpeckers excavate nest cavities in live or dead trees. Secondary nesters then use these cavities. Once trees have decayed to a point where there are no longer branches, it is classified as a snag (< 20 feet tall is a stub). Many insectivorous birds will use the snag for foraging. Finally the snag will either topple to the ground or wear to a stump. The fallen log provides habitat for carpenter ants. In addition, amphibians and reptiles will live in and under the rotting wood; small mammals also utilize the downed logs.

In addition to the stages of decay, other variables determine a particular snag's value to specific wildlife species. Characteristics such as tree size, location, species, and how it was killed are important determinants of wildlife use (DeGraaf and Shigo 1985). In general, when managing for cavity trees, the rule "bigger is better" applies. Large birds need large diameter trees to excavate nesting cavities. Smaller birds are able to find nest sites in large trees, but it does not work the other way. In addition, large snags usually stand longer than smaller ones. Emphasis is often placed on managing for viable woodpecker populations because their success will provide enough nesting sites for secondary cavity nesters. **Table 54** gives the number of cavity trees necessary to sustain the hypothetical maximum populations of nine woodpecker species found in New England.

Figure 20: Decomposition of Snags and Coarse Woody Debris

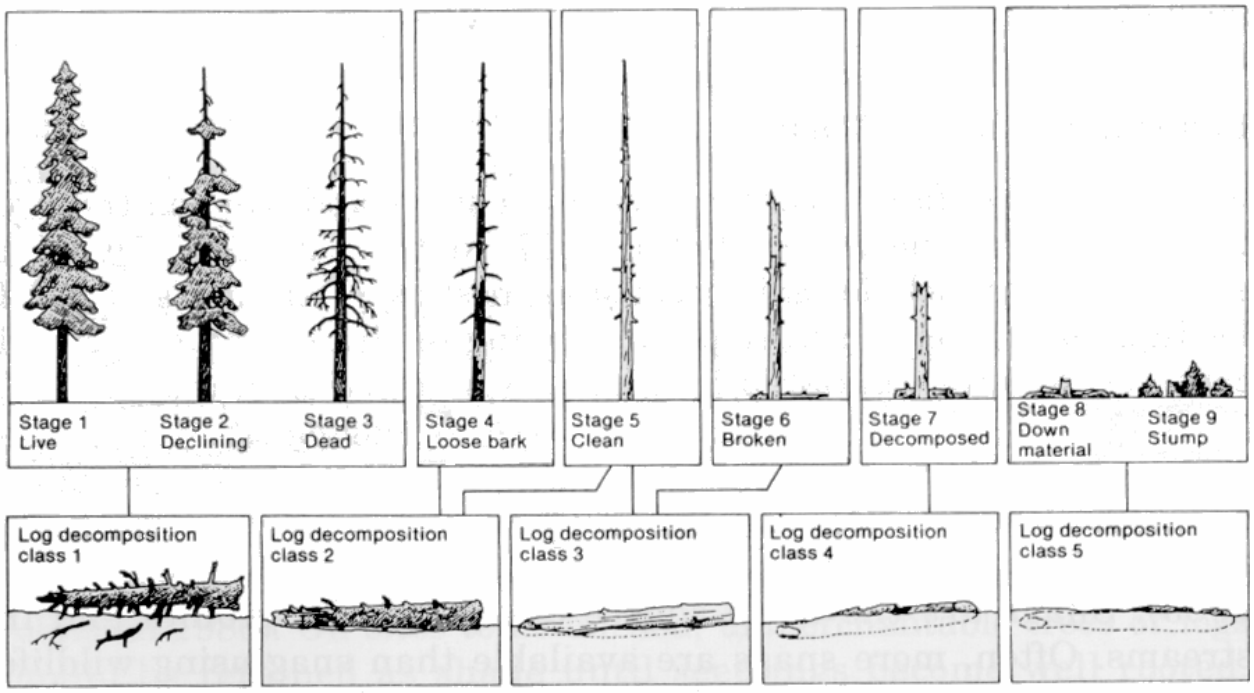


Table 54: Number of Cavity Trees Needed to Sustain New England Woodpecker Populations

Species	Territory Size (Acres)	Avg. Nest Tree[1]		(A) Cavity Trees Used, Minimum (N)	(B) Pairs/100 acres, Maximum (N)	(C) Cavity Trees Needed/100 acres[2] (AxB) (N)
		DBH (in.)	Height (ft.)			
Red-Headed Woodpecker	10	20	40	2	10	20
Red-bellied Woodpecker	15	18	40	4	6.3	25
Yellow-bellied Sapsucker	10	12	30	1	10	10
Downy Woodpecker	10	8	20	4	10	40
Hairy Woodpecker	20	12	30	4	5	20
Three-toed Woodpecker	75	14	30	4	1.3	5
Black-backed Woodpecker	75	15	30	4	1.3	5
Northern Flicker	40	15	30	2	2.5	5
Pileated Woodpecker	175	22	60	4	0.6	2.4

Source: DeGraaf and Shigo, 1985.

[1] Larger trees may be substituted for smaller trees. [2] Number of cavity trees needed to sustain population at hypothetical maximum level.

5.4.3.1.6.2 Den Trees

Management Objective: DWSP will provide a continuing supply of good to excellent quality den trees, distributed over time and space in order to maintain self-sustaining populations of all cavity dependent wildlife. In areas where good den trees are lacking, poorer quality trees will be retained until better trees develop.

Recommended Practices:

- Retain as many live trees with existing cavities and large unmarketable trees as possible.
- When possible, retain all trees > 29” dbh or at a minimum 2 or more trees >29” dbh per 100 acres.
- Leave at least 1 tree 15-29” dbh per acre.
- Leave at least 1 tree per acre that shows potential for developing into a den tree (broken top, large broken limbs, fire scar); oaks, sugar maples, ash, and hemlock are good trees to select because they readily form natural cavities or are long-lived.
- Leave all den trees within 100 feet of a wetland or riparian area.

Den tree

Den trees are living, hollow trees used by a variety of mammals including mice, raccoons, squirrels, and bears. In general, there are usually fewer den trees available in an area than could be used by wildlife because large (>15" dbh) rough or rotten trees are relatively rare.

Unlike cavity trees, which have central columns of decay, den trees are hollow or have large hollow limbs, but are still alive and vigorous. Den trees usually have easily visible openings in the sound wood. Some heavily used den trees (e.g., by raccoons) are hardwoods with the top snapped off. Den trees usually have low commercial value, but their value to wildlife is extremely high and long lasting. It may take 100 years to develop large den trees, and once developed some trees (oaks, sugar maple) can live for several hundred years (DeGraaf and Shigo 1985). Once den trees die and fall to the ground, the remnant hollow log may last 25 years, providing breeding habitat for redback salamanders and ringneck snakes.

5.4.3.1.7 Downed Woody Material

Management Objective: DWSP will continue to maintain a range of sizes and types of downed woody material and retain or provide downed woody material in sites where it is lacking.

Recommended Practices:

- Leave snags in place if they must be felled during management operations.
- Avoid damaging existing downed woody material during harvesting, particularly large (>16" dbh) hollow logs and stumps.
- Leave, when possible, at least 4 logs of decay class 1 and 2 per acre; at least 2 of these logs should be >12" dbh and >6 feet long. Hollow butt sections of felled trees can be used. (See **Fig 20** above).
- Retain as many logs as possible of classes 3, 4, and 5. (See **Fig 20** above).
- On slopes, orient logs along contours and place against stumps when possible. In full overstory removals, leave slash on at least 10% of the site in scattered piles or rows.
- Do not add debris to streams and avoid disturbing woody material already in stream.

Downed woody material refers to slash, logs, large and small limbs, stumps, and upturned tree roots that accumulate on the ground either naturally or through forestry operations. Downed woody debris provides food, cover, and nursery habitat for a range of flora, fauna, and fungi. Downed woody material provides critical wildlife habitat and is used for nesting, shelter, drumming, sunning, as a source and place to store food, and as natural bridges. The specific value of downed woody debris depends on the physical distribution, amount, size, degree of decay, and orientation of debris relative to slope and exposure (Flatebo et al., 1999). Decaying logs also serve as nurse-trees for seedlings and colonization sites for fungi. Too much or too little downed woody material can be detrimental to wildlife. In general, it is best to retain or produce downed woody material that is distributed similarly to what might occur naturally as coarse woody debris in the given stand type (often random and clumped rather than evenly distributed).

Downed woody material.

Logs are generally considered to be the most valuable downed woody material because of their slow decay and longer persistence. Long logs >16" dbh are especially important wildlife habitat features. As logs age and decay their role as wildlife habitat shifts. Logs supported by branches provide shelter, feeding, and display sites for a variety of birds and mammals. As the log settles to the ground and continues to decompose it may be used by small mammals, snakes, toad, and salamanders for shelter, food, and travel. Large logs with hollow portions may be used as den sites by larger mammals.

5.4.3.1.8 Woodland Raptor Nests

Management Objective: DWSP will maintain suitable nesting sites for woodland raptors across the landscape over time and will avoid disturbing nesting pairs of raptors.

Recommended Practices:

- Contact Division's wildlife biologist when planning forest management activities in the vicinity of a bald eagle nest.
- Inspect mature white pine and hardwood trees for large stick nests when cruising timber. Do not cut trees, when possible, containing large stick nests and hardwoods with 3-pronged forks.
- Maintain an uncut buffer of at least 66 feet around active raptor nest trees and retain 65-85 percent canopy closure within 165 feet of large stick nests in closed-canopy forests.
- Maintain an uncut buffer of at least 66 feet around nest tree if an active raptor nest is located before or during a scheduled harvest operation; do not harvest within 330 feet of the nest during April-June.
- Harvesting schedules and buffer zones may be relaxed if an active raptor nest can be positively identified as belonging to a common or tolerant species (e.g.., red-tailed or broad-winged hawk).
- Retain several super-canopy pines near the reservoir shoreline as potential future nest trees for bald eagles.
- Follow appropriate snag tree management guidelines.

Hawks, owls, falcons, and vultures are known as raptors. There are 19 species of raptors that breed in New England. Sixteen of the 19 species are known or potential breeders at the Quabbin (**Table 55**). Most raptors are predators that feed upon birds, mammals, fish, amphibians, insects, and snakes. While most raptors will eat a variety of animals, some species like the osprey have much narrower food requirements. Compared to other birds, raptors require relatively large home ranges (60->900 acres) in order to meet their food and nesting requirements. Raptor nests are widely dispersed across the landscape in a variety of habitats and forest conditions.

Some raptors will build a new nest each year within their territory, while other raptors will use the same nest for a number of years or claim the nest built by another species. Raptor nest trees must be large and strong enough to support nests ranging from 18" in diameter (broad-winged hawk) to over 3 feet (bald eagle, northern goshawk) (Flatebo et al., 1999). Large diameter broken stubs, closely spaced branches halfway up large white pines, and 3-pronged main forks of mature hardwoods are most frequently used by stick nest building raptors. By maintaining existing nests and identifying potentially good future nest trees, an area's raptor population can be maintained over a long period.

Many raptors nest early in the year. By February-March, most great-horned owls and some red-tailed hawks and barred owls are incubating eggs. Most other raptors will be incubating by May. Nesting raptors can be vulnerable to human disturbance. There is a wide range of tolerance depending on the species. Some intolerant species (bald eagles, goshawks) may abandon the nest during the early weeks of

incubation. Repeated flushing of the female from the nest may also subject the eggs to fatal chilling or the young to predation.

Identifying active nests is critical to ensuring their protection and establishing a buffer zone to minimize disturbance. The easiest, and unfortunately most infrequent, way to detect active nests is to see birds in or around the nest. However, active nests can be identified when no birds are visible by looking for the following indicators:

1. Prior to laying their eggs, some raptors 'decorate' the nest with fresh branches, usually from a conifer.
2. After hatching, whitewash (excrement), regurgitated pellets, and prey remains may be found on the ground near the nest tree.
3. Raptor nests can be distinguished from squirrel nests by their shape (squirrel nests are saucer-shaped) and lack of leaves (squirrel nests are made mostly of leaves).

Bald Eagle nest

Table 55: Known and Potential Breeding Raptors at Quabbin

Species	Breeding Status	Nest Site Selection
Turkey Vulture	Breeder	Rocky outcrops, ledges, cavities
Osprey	Potential Breeder[1]	Stick nests in trees, snags, poles
Bald Eagle[2]	Breeder	Stick nests in living trees
Northern Harrier[2]	Potential Breeder	On ground, over water
Sharp-shinned Hawk[2]	Potential Breeder	Stick nest on tree limb-usually conifers
Cooper's Hawk[1]	Potential Breeder	Stick nest (may use old crow nest) on horizontal branch in hardwood or conifer
Northern Goshawk	Breeder	Stick nest (used or new) in hardwood
Red-shouldered Hawk	Breeder	Stick nest (new) in tall tree
Broad-winged Hawk	Breeder	Stick nest in tall tree
Red-tailed Hawk	Breeder	Stick nest in oak/white pine
American Kestrel	Breeder	Cavity, nest box
Barn Owl[2]	Non-Breeder	Cavities, buildings, artificial
Screech Owl	Breeder	Cavities and woodpecker holes (Pileated/Flicker)
Great-horned Owl	Breeder	Cavities, old crow, hawk, or heron nests
Barred Owl	Breeder	Large natural cavities or old bird nests
Long-eared Owl[2]	Potential Breeder	Old crow/hawk nest or natural cavity
Saw-whet Owl	Breeder	Natural cavity or woodpecker hole
Short-eared Owl	Non-Breeder	Open fields, heath on Cape/Islands
Peregrine Falcon	Potential Breeder	Cliffs, tall buildings, urban areas

Source: adapted from DeGraaf and Rudis 1986
[1]Potential breeders are raptors not known to be currently breeding within the Quabbin watershed, but given the bird's range and habitat requirements it could breed there in the future.
[2]Listed with the Massachusetts Natural Heritage and Endangered Species Program as an endangered, threatened or special concern species.

5.4.3.2 Considerations during Timber Marking, Harvesting, and Other Land Management Activities

While careful planning and preparation can mitigate many of the potentially negative impacts on wildlife resources, some specific impacts or events cannot be discovered until operations begin in the field. Locations of active raptor nests, quality den and snag trees, and seeps may not be discovered until foresters begin marking individual trees in a lot. It is during these detailed lot inspections that some of the specific wildlife habitat management recommendations can be implemented. In addition, broader considerations such as timing of operations, harvesting techniques, record keeping, and other miscellaneous considerations should be addressed.

5.4.3.2.1 Timing of Operations

The timing of land management activities can have a dramatic impact on wildlife species. Some species (bald eagle, great-blue heron, and coyote) are extremely sensitive to human disturbance and may abandon or forgo breeding when repeatedly disturbed. Fortunately, some sensitive species can be easily identified or have known nesting sites. Great-blue herons nest in visible colonies, usually in dead snags over water. In addition, bald eagles build large stick nests that are easily seen and may be used for many years. However, for most other species their nest, burrow, or den is well hidden and would not be discovered until an operation had already begun. Luckily, most wildlife species tend to nest or den during the spring and early summer when land management activities are restricted.

When conflicts do arise, the following procedure will be followed:

1. Division personnel will notify the wildlife biologist when land management activities have clearly disrupted a rare or uncommon species' breeding efforts.
2. The Division wildlife biologist will assess/determine the nature of the nesting/denning activities, the species involved, stage of breeding (courtship, incubation, brooding), and initial response to the disturbance.
3. The Division will determine what options will be used to mitigate and avoid further disturbance during the remainder of the breeding season.

Land management activities conducted at other times of the year may unknowingly impact wildlife species, and efforts should be made to reduce these conflicts. Maintenance (mowing, burning, etc.) of fields and open areas should only be done in early spring (March/April) or after August 1 to avoid destroying nesting birds and mammals. No activity should occur in or near seeps during winter. If possible, winter activity should be avoided in and around identified wildlife wintering areas.

In some cases, activity during certain times of the year is preferred. Working around vernal pools is often best during winter when frozen/dry conditions minimize rutting and disrupting the forest floor. Further, logging during the fall and winter usually has minimal impact on most wildlife species and may actually benefit some animals by providing additional browse and cover.

Land management activities conducted at any time of the year have the potential to disrupt some wildlife species. However, this disruption is usually small in scale and scattered over the watershed. The benefits derived from actively managing the land outweigh the localized disruption. Because impacts cannot be avoided everywhere, the Division will:

- Continue to gather data on critical and sensitive wildlife and their habitats on the watershed.
- Assess the potential impacts of the timing and location of operations on a case-by-case basis to avoid impacting special concern species.
- When feasible, shift the timing or location of an operation to avoid these impacts.

5.4.3.2.2 Harvesting Techniques

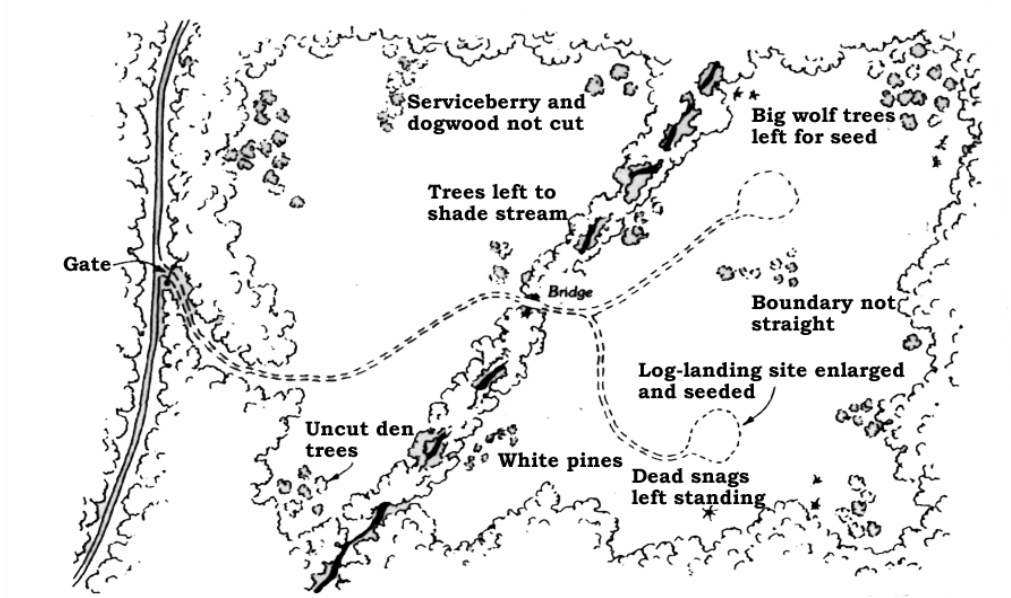
5.4.3.2.2.1 Group Selection Considerations

When forestry operations use group selection to remove trees in openings 1 acre or greater in size, certain techniques and considerations can be used to enhance the area for wildlife. With proper planning, harvesting operations can be conducted while still maintaining snags, den trees, and mast producing trees within the opening (**Figure 21;** see Section 5.4.3.1). Note that while creating an irregular border on these openings increases edge habitat and will benefit those species that prefer edges, this same phenomena may increase predation on songbird nests and increase browsing on regeneration within the opening, among other undesirable effects (Hunter, 1990).

5.4.3.2.2.2 Logging and Skid Roads

Access roads are used by the Division to remove wood, control fires, maintain watershed structures, and aid in navigation (see Section 5.3.6). Most Division roads within the watershed are narrow, grassy woods trails often referred to as logging roads. While roads are necessary to the Division, they can also act as barriers to animal movements and fragment the forest. The Division's use of uneven-aged management requires harvest operations to extend over a relatively large area and use comparatively short cutting cycles (20-30 years). As a result, an extensive network of roads are created and maintained, although careful planning can and should hold this network to a minimum.

Figure 21: Forest Opening Planned with Wildlife Considerations



The effect of forest roads on wildlife and biodiversity depends on the size, type and location of the road. The frequency with which a road is used and its proximity to other travel routes will also determine its impact. Roads effectively create an edge habitat that benefits some species, but has negative effects on species sensitive to disturbance or predators. Roads are often used by some wildlife species as travel lanes, but they may impede the movements of other species that require continuous vegetative cover. Roads may also fragment the forest and isolate individuals or populations.

Constructing and maintaining forest roads on Division property constitutes a relatively permanent change in the habitat structure of the area. Because traffic on Division roads, particularly at night, is minimal, there is little concern about direct mortality on wildlife populations. The more general concern is that a strip of dirt or gravel under an open canopy can serve as a physical or psychological barrier to animal movements (DeMaynadier and Hunter 2000). Studies have documented this barrier affect for small mammals and invertebrates (see DeMaynadier and Hunter 2000). In addition, DeMaynadier and Hunter (2000) recently documented the barrier affect of forest roads on salamanders.

When logging roads, skid trails, and landings are being planned, certain design features can be incorporated to minimize wildlife impacts:

- Logging roads/skid trails should avoid vigorous patches of shrubs.
- New logging roads should be minimized and existing roads should be upgraded instead if possible.
- Roads should be as narrow as possible, ideally one-lane with occasional turnouts.
- Circular routes should be avoided; a cul-de-sac design is better.
- Abandoned logging roads, skid trails, and landing sites should be seeded, when possible, with a grass-legume mixture.
- Road intersections should be angled to limit line of sight.

5.4.3.2.2.3 Record Keeping

Division Foresters, Rangers, and other natural resource managers spend a large amount of time walking, observing, and assessing lands within the Quabbin watershed. It is likely that they may observe

significant wildlife or important wildlife habitats. Because of the size of the watershed, these anecdotal observations are a critical source of biological information, and may be key to avoiding or mitigating potential wildlife impacts of future land management activities. These observations will be reported to the Division wildlife biologist so that records may be routinely maintained and updated.

5.4.3.2.2.4 Miscellaneous Considerations

The Division's silvicultural practices include cutting trees with weak crown forms that are more susceptible to damage. Some of these trees have wildlife value, and Division foresters should continue to leave some of these trees uncut. For example, trees growing on an angle ("hurricane-tipped") serve as travel routes for arboreal mammals from the ground to the forest canopy. In addition, older trees with large stocky limbs often have protected crotches that are used by nesting birds and mammals. These trees also typically have a high potential for cavity formation. While it is not necessary to maintain all examples of these trees, it is important to retain some during harvesting operations.

Particular combinations of trees species are also valuable to wildlife. Mature oak trees within hemlock or other conifer stands provide food resources within wildlife wintering areas. Small pockets of hemlock within hardwood stands can serve as significant wildlife cover. Both of these habitat conditions should receive special treatment when feasible.

5.4.3.2.3 Natural Heritage and Endangered Species Program Conservation Management Practices for Listed Wildlife Species (WCMPs)

The Natural Heritage & Endangered Species Program (NHESP), in collaboration with DCR's Division of Water Supply Protection, DCR's Bureau of Forestry, and the Massachusetts Division of Fisheries and Wildlife's Forestry Program, is currently preparing wildlife conservation management practices (WCMP) documents for certain rare species that are listed and protected by the Massachusetts Endangered Species Act (MESA). These WCMP documents will provide information on the rare species' life history and habitat requirements and make scientifically-based recommendations on how to minimize potential adverse impacts of forestry activities. The goal of these recommendations is to protect rare species populations and maintain rare species habitats for long-term viability while maintaining the opportunity for the sustainable management of the state's forests.

The rare species information forming the basis of these documents has been gathered from a variety of sources. Information on specific rare species and their habitat requirements has been compiled from published scientific articles, books, unpublished reports, NHESP data, existing management guidelines from other states, and consultation with researchers who have first-hand experience with the species in Massachusetts.

The NHESP will use these recommendations in its review of specific Forest Cutting Plans. The existence of the WCMPs will improve the speed and consistency of the NHESP's reviews of Forest Cutting Plans and will make the outcome of the Cutting Plan reviews more predictable to the forestry community. These recommendations do not supersede any law, regulation, or official policy of this or any other agency. Rather, these guidelines are intended to complement existing regulatory review processes by providing up-to-date, scientifically-based management recommendations for forestry activities as they impact specific species.

Although the best available scientific information, researchers, and managers were consulted in preparing these documents, it is expected that new information will arise about the species' requirements and their response to habitat modifications. With the recognition that both forestry practices and rare species conservation require adaptive management it is acknowledged that the recommendations in these documents may need to be updated and revised in the future.

5.4.4 Population or Impact Monitoring and Control Plans

5.4.4.1 Beaver

5.4.4.1.1 Aquatic Wildlife Pathogen Control Zone

There is extensive research documenting the role of certain wildlife species in the transmission and amplification of water-borne pathogens. In order to address these concerns, the Division developed a control program to identify, remove, and study critical wildlife species from a defined area around the Chicopee Valley Aqueduct (CVA) Intake (for a complete description of the program see **Quabbin and Wachusett Reservoir Watersheds Aquatic Wildlife Pathogen Control Zones,** MDC 1999).

The program began in 1999, and it specifically targets beaver and muskrat populations living within the defined control zone (the cross-hatched area in **Figure 22**). Routine surveys are conducted within the zone, and any individuals of beaver or muskrat that are located are immediately removed. In addition, other activities are conducted to discourage animals from occupying the sites, including habitat modification and removal of lodges and dams. Control activities take place year-round through a special agreement with MassWildlife.

Since 2004, fecal samples have been collected from removed animals. Samples are tested for the presence of *Giardia spp.* and *Cryptosporidium spp.* Early results of this ongoing study indicate a relatively low rate of infection.

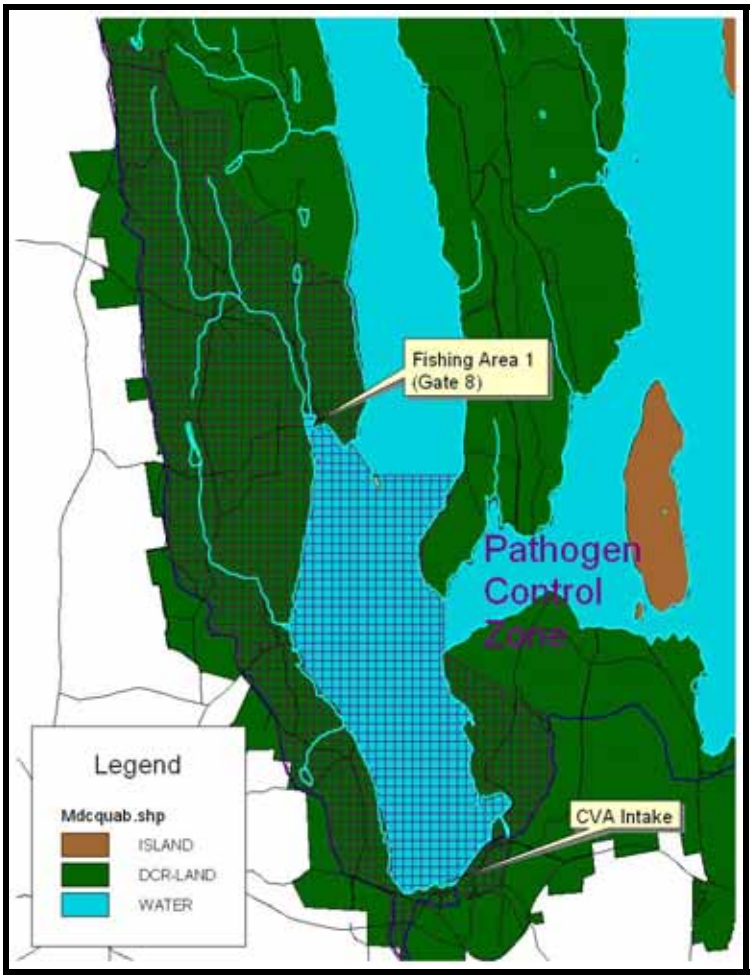
5.4.4.1.2 Beaver Sites outside the Pathogen Control Zone

Beaver can dramatically alter their surrounding habitat, which in turn can affect other wildlife species and humans. Beaver can cause localized damage to roads, culverts, and trees, although the habitat they create is seen as beneficial to a variety of wildlife species. Whether any one colony is seen as beneficial or detrimental depends on the resources affected. Division policy regarding beavers takes into account the variety of situations that may arise and applies solutions as needed to offer the best long-term remediation. Because beaver issues can become quite controversial, it is important to present the range of potential beaver impacts on riparian vegetation, water quality parameters, and the general ecology.

5.4.4.1.2.1 Beaver Induced Alterations of Riparian Systems

Beaver are one of the few wildlife species that have the ability to dramatically alter the surrounding habitat to their benefit. These habitat alterations can have potentially substantial impacts on the ecosystem. Changes in vegetation, biotic and abiotic features of the wetland, and impacts to other organisms may result. Riparian areas, particularly second- to fourth-order streams and adjacent low-lying areas are often colonized by beaver (Hammerson 1994). The presence or absence of beaver in an area or region can have a dramatic impact on the predominant vegetation. For example, in West Virginia, the widespread swamp forests common in the early 1900s were most likely the result of the eradication of beaver from the state by the early 1800s (Land and Weider, 1984 in Hammerson 1994). Most Division owned riparian areas are primarily forested with a variety of tree species. It is interesting to note that these forested wetlands in Massachusetts may also be an artifact of the beaver's eradication from the state by the late 1700s until their eventual return in 1928. As a result, changes to the riparian landscape caused by expanding beaver populations during the last 20-30 years may appear even more dramatic because they were absent from the ecosystem for many decades.

Figure 22: Pathogen Control Zones at Quabbin



The Division's primary interest is to preserve and protect water quality within the water supply reservoirs, and riparian areas are an important component to that protection. As a result, it is helpful to summarize the impacts of beaver on the biotic and abiotic components of riparian ecosystems in order to address potential negative impacts from their occupation of riparian areas. One of the most important factors related to changes in the environment is the structural integrity of beaver dams. Many of the components associated with beaver occupation of riparian zones are contingent on the longevity and stability of the dam itself. Dams that continually wash out may cause water quality problems associated with flooding and the sudden release of sediment and accumulated nutrients. It is usually dams on larger streams (above fourth-order) that are prone to washouts (Naiman et al., 1988). Many of the streams within the Quabbin watershed are first- to second-order streams, although there are larger streams (East and West branches of the Swift River) that are fourth- to fifth-order streams. Any beaver dams located on these higher order streams would be much more prone to wash-outs.

5.4.4.1.2.2 Beaver Effects on Vegetation

Beaver are strictly herbivores and have been described as choosy generalists (Novak, 1987). Beaver are also central place foragers because they return to their lodge or bank den after feeding (Naiman et al., 1988). This is a critical behavioral trait and, as a result, beaver foraging is restricted to a relatively narrow band of forest surrounding their pond (Johnston and Naiman, 1990). One study indicated that beaver fed preferentially on a few number of deciduous species and the number of stems cut declined sharply as distance increased from the pond (Donker and Fryxell, 1999). Barnes and Mallik (2001) found that 91%

of all beaver cut stems were within 20.1 m of the pond shoreline. Beaver will cut and consume a variety of woody vegetation in addition to feeding on aquatic vegetation during the spring and summer. Beaver do have a strong preference for certain species, particularly members of the aspen family.

When beaver colonize a new riparian area, several important events take place. Typically, a dam is constructed, and the raised water level kills trees within the flood zone. In addition, beaver cut down some trees along the shoreline. Although a substantial number of trees may be lost due to flooding, the wetland continues to be buffered by a forested habitat. The forested zone has been pushed back to where the high water level now occurs as opposed to lining the stream bank. Along the shoreline, some canopy trees are killed or toppled by beaver, allowing more light to reach the forest floor. Increased light, along with a decrease in competition for water and nutrients, will stimulate regeneration and a release of the forest understory (Johnston and Naiman, 1990). The light penetration may be sufficient to allow regeneration of shade-intolerant species (Donker and Fryxell, 1999). The amount of canopy being removed along the shoreline can vary. After 6 years of continuous occupation, one study site had a 43% reduction in basal area of stems >2 inches dbh (Johnston and Naiman, 1990). Other studies have indicated that perceived damage and actual damage to forest resources may be quite different. King et al., (1998) indicated that beaver in a wetland in the southern United States were having minimal effect on the forest. In this case it was determined that although tree damage was highly visible by casual observation, beaver were having little impact on tree survival.

In some cases where the overstory is primarily comprised of aspen (some western streams), a majority of the overstory may be removed, and the riparian area could go through a shrubby woody stage until non-browsed species grow and overtop the shrub layer. On the Quabbin watershed, aspen species are a relatively minor component to forested riparian areas. Most riparian areas consist of a diversity of species, making it less likely that all trees will be removed, although the shrubby component to the riparian area may become more dominant as some canopy trees are lost.

Beaver induced changes to vegetation along riparian zones can be quite dramatic when compared to conditions prior to beaver occupation. The primary result of these changes will be a shift in the species composition before and after beaver occupation. The shift may be undesirable if the species being lost are of high economic value (pine, oak, etc.). This is a particular problem in many southern states. In summary, the riparian wetland, although different, is still buffered by a forested habitat that may be more diverse and/or contain a larger shrubby component.

5.4.4.1.2.3 Beaver Effects on Water Quality

The Division manages beaver within the defined Aquatic Wildlife Pathogen Control Zone to control pathogen transmission (see Section 5.4.4.1.1). However, because beaver can alter the hydrologic regime of a riparian area, it is important to consider their impact with regards to general water quality parameters. As mentioned in Section 5.4.1.2.1.1, most streams within the Quabbin watershed are low-order (first-to-third) systems, and beaver dams constructed in these sites are most likely to exist in stable conditions for many years.

In many situations, beaver dams can transform a lotic system into a lentic habitat that may resemble a lake or pond*. Some important changes associated with this transformation include increased water depth, elevation of the water table, an increase in the wetted surface area of the channel, and storage of precipitation, which is gradually released (Hammerson 1994). In addition, the storage of precipitation can reduce variability in the discharge regime of the stream (Hammerson 1994). Ponded riparian areas have an increase in aerobic respiration. Respiration is 16 times that found in a riffle (per linear meter of

* Lotic refers to aquatic communities found in running water. Lentic referes to aquatic communities found in standing water.

channel) (Hammerson 1994). In low-order streams there is a shift to anaerobic biogeochemical cycles in soil layers beneath the aerobic pond sediments (Hammerson 1994).

Ponded areas behind beaver dams reduce current velocity within the riparian area, which decreases erosion and stabilizes streambanks (Brayton 1984, Hammerson 1994). In some western states beaver were introduced into riparian ecosystems that had eroded streambanks and little vegetation along the shoreline (Brayton 1984). The result was a dramatic decrease in sediment transport downstream, streambank erosion was stabilized, and diversity of vegetation began to grow (Brayton 1984). In addition, by slowing down water velocity there is increased trapping of sediments behind beaver dams, and a resultant decrease in turbidity downstream (Brayton 1984, Hammerson 1994, Maret et al., 1987, Naiman et al., 1994, Naiman et al., 1988). Several studies have shown a substantial amount of sediment being collected behind beaver dams, ranging from 1.5-6 feet (Hammerson 1994, Meentemeyer and Butler 1999). Meentemeyer and Butler (1999) suggest that if beaver are eliminated from a landscape, basin sediment yields could increase dramatically. Having beaver present in a watershed in turn would help minimize sediment transport and stabilize stream banks (Meentemeyer and Butler 1999).

Changes in the chemical and physical properties of the stream occur when an area is dammed. Generally there is a reduction in Dissolved Oxygen (DO), Aluminum (Al), and Sulfate (SO_4^{2-}), and an increase in pH, dissolved organic carbon (DOC), Iron (Fe), and Manganese (Mn) (Smith et Al., 1991; Hammerson 1994). DO reduction was most likely the result of increased retention of organic matter and associated decomposition processes (Smith et al., 1991). By trapping large amounts of sediments and particulates, beaver ponds can also trap associated nutrients, including phosphorus (Maret et al., 1987). Phosphorus (P) is an important element in water supply reservoirs because it is often the limiting factor in the growth of aquatic plants and algae in reservoir systems (Lyons 1998). Other studies have shown that beaver activities may actually increase concentrations of P within the impoundment (Klotz 1998). However, in these studies it is clearly shown that increased concentrations of P only occur for short distances downstream of beaver ponds before equilibrium processes reduce the concentration (Klotz 1998). .

One potential problem associated with beaver is the increase in DOC within the beaver pond. Though DOC does not directly affect drinking water quality parameters, it is a concern because of disinfection by-products. DOC in beaver ponds increases for several reasons. First, a large amount of wood is transferred into the stream channel, either directly through cutting or indirectly through flooding. In addition, more leaves are collected within a pond than in a stream channel. The carbon turnover rate for this material is less in a ponded area than in a stream with flowing water Hammerson 1994). Margolis et al., (2001) found average DOC concentrations 10 m and 100 m downstream of a beaver impoundment were significantly higher than DOC concentrations upstream of a beaver pond or 1 m below the impoundment. Although increases in DOC are a potential concern, a recent study conducted at Quabbin suggested that biological processes and the sheer size of the reservoir prevented these elevated DOC levels from reaching the intake (Garvey 2000). In fact, this study suggests that algae are a much greater concern regarding disinfection by-products at reservoir intakes.

The overall effect of ponding riparian areas is the translocation of chemical elements from the inundated upland to the pond sediments or downstream. A portion of the chemical elements are transported downstream, while most are accumulated in the pond sediments and are available for vegetative growth if the pond drains and succession begins (Naiman et al., 1994).

5.4.4.1.2.4 Ecological Impacts of Beaver

There are ecological impacts as the beaver transforms the stream channel into a ponded area. The most immediate effect could be the potential loss of habitat for species either requiring large expanses of deciduous trees along a stream or those species living within the stream channel. Because a beaver dam influences only parts of a riparian area, it is unlikely that beaver activity would result in the disappearance

of species relying on wooded streams. In New York, experts agree that even after 30 years of expanding beaver populations, species or communities requiring wooded wetlands were probably not adversely affected on a regional or statewide level (Hammerson 1994).

There is often a good deal of concern regarding cold water fisheries and the impacts of beaver impoundments. It is likely that beaver both enhance and degrade suitable fish habitat. Hägglund and Sjöberg (1999) indicated that beaver enhance fish species diversity in Swedish streams. In addition, they speculate that beaver ponds serve as habitat for larger trout in small streams during drought periods. Snodgrass and Meffe (1998) indicated that in low-order streams, beaver had a positive effect on fish species richness. The maintenance of this effect however required the preservation of the dynamics of beaver pond creation and abandonment. The warming of stream water is often cited as a cause of concern regarding cold water fish habitat. A study done in Maryland and Pennsylvania reported that water temperatures were significantly greater downstream of beaver dams during the fall, spring, and summer (Margolis et al., 2001). McRae and Edwards (1994) indicated that large beaver impoundments would often warm downstream temperatures slightly, but they also served to dampen temperature fluctuations immediately downstream. In addition, when beaver dams were experimentally removed, there was no reduction in the difference between upstream and downstream temperatures. In some cases, dam removal increased the warming rate of the stream (McRae and Edwards 1994). It has been suggested that air temperature (not impoundments) is the single most important determinant of stream temperature in the absence of direct thermal inputs (McRae and Edwards 1994).

The impact on other organisms is less understood. Russell et al., (1999) reported that species richness and abundance of amphibians were not significantly different among old beaver ponds, new beaver ponds, and unimpounded streams. Reptiles did show a difference among sites. Richness and total abundance of reptiles was significantly higher at old beaver ponds (Russell et al., 1999). Another study found no significant differences in overall herpetofaunal abundance between uninterrupted streams and beaver ponds (Metts et al., 2001). However, significantly more salamanders were captured at uninterrupted streams and significantly more anurans, lizards, and turtles were captured at beaver ponds (Metts et al., 2001).

Invertebrate communities exhibit a strong ecological shift as running water taxa are replaced by pond taxa when streams are impounded. This results in an increase in the number of collectors and predators and a decrease in the number of shredders and scrapers (Naiman et al., 1988). While total density and biomass may be 2-5 times greater in ponds than riffles, the total number of species in ponds and streams appear to be similar (Naiman et al., 1988).

5.4.4.1.2.5 Summary

Beaver populations within the Quabbin watershed continue to fluctuate as beaver mortality rates remain low. As beaver continue to colonize riparian areas, it is important to recognize their role in hydrologic and ecological processes. A careful review of the literature would indicate that it is not the presence of beaver dams themselves but their persistence through time that has the biggest potential impact on water quality. The results of one study suggested that beaver ponds could improve water quality if they were located in the right locations; the authors deduced that it is the downstream channel that has the largest impact on water quality: “Our data illustrate the importance of location of beaver ponds along a stream in improving water quality. If water quality is to be maintained downstream from ponds and if nutrient export to a lake or reservoir is to be reduced, then the channel downstream from the pond complex must be stable or the pond complex must be located close to the lake or reservoir”(Maret et al., 1987). Most streams within the Quabbin watershed are low-order (first to third), and beaver dams constructed across these streams have the strong potential for long-term stability and persistence. On those sites with historically unstable beaver dams or on particularly “flashy” streams, beaver control will be addressed as described in section 5.4.4.1.3.

Some water quality parameters are changed or modified when beaver dam riparian areas. Generally, there is a reduction in DO, and an increase in DOC, pH, and Fe. Some studies have suggested that these changes may carry at least 100m downstream of an impoundment. Most evidence would suggest that beaver ponds (like most wetlands) have either no negative effect on water quality or have a filtering effect that improves water quality by decreasing erosion, trapping sediments, particulates, and nutrients. Changes to vegetation along the banks of beaver ponds results in a species shift away from species preferred by beaver or economically valuable deciduous trees to a larger proportion of woody shrubs and unpalatable or undesirable (by beaver) canopy trees. The more open canopy that results from beaver activity stimulates regeneration and increases habitat diversity.

Overall, there appear to be either no effects or positive effects on both faunal species richness and diversity when comparing ponds to unaltered riparian wetlands. There are still site-specific situations where beaver will need to be controlled as detailed in the next section. Outside these specific situations where damage is occurring, there does not appear to be a need for the Division to focus beaver control efforts on a watershed basis.

5.4.4.1.3 Beaver Management Policy

It is the Division's general policy to allow unrestricted beaver occupation. However, the following situations are examples where beaver activity may be discouraged, mitigated, or modified:

- Beaver activity that threatens rare or uncommon plant or animal communities.
- Beaver activity that precludes the use of necessary access roads needed for watershed maintenance, management, or protection.
- Beaver activity that threatens the proper functioning or structure of dams, culverts, and other parts of the water supply infrastructure.
- Beaver dams on unstable or flashy streams with a history of, or potential for, regular washouts.

The following procedure will be used to mitigate the damage when there is a conflict with a beaver colony. Division personnel encountering problem beaver sites should fill a *Beaver Damage Observation Form* and return it to the Division wildlife biologist and Quabbin/Ware River Regional Director. Upon review, the wildlife biologist and Regional Director will decide the most appropriate control activity for each site. Options available include: water level control devices, dam stabilization, culvert protection, or lethal removal. Site-specific control options will be chosen based on site conditions, history of the site, and type of damage occurring. The goal is to provide the most effective control possible that mitigates the problem. Appropriate permits will be obtained when necessary (e.g., removing a section of dam to install a flow control pipe).

Lethal removal will be a viable option, but will only be used if all of the following criteria for the site are met:

- Beaver are causing documented (observation, photographs, etc.) damage to DCR infrastructure (roads, culverts, bridges).
- Other, non-lethal means (water level control devices, fencing, etc.) would not be able to mitigate the problem because of limitations in access, maintenance, or effectiveness.
- DCR property being damaged is essential and cannot be temporarily abandoned.

- Lethal measures can be implemented within appropriate laws and guidelines and without threat to the safety of the public, domestic animals or other wildlife.

When lethal measures are to be used, the following procedure must be followed:

- The above criteria must be documented prior to action (using *Beaver Damage Observation* Form).

- Beaver will be removed through shooting (12 gauge shotgun), or live-trapping during the beaver trapping season using Hancock, Bailey or cage traps and then shooting.

- Two staff will be present at all time and will include one supervisor. The supervisor will be a Water System Storage Foreman II or higher. All staff participating will have a Firearms ID card. Any persons using live-traps must be properly trained.

- Every attempt will be made to retrieve beaver carcasses, and upon retrieval a fecal sample will be collected and then the animal will be buried at a suitable location.

- Personnel taking part in beaver control activities will take adequate precautions (washing hands/wearing rubber gloves) to prevent possible transmission of *Giardia* and *Cryptosporidium* and other pathogens.

- The supervisor in charge will document all actions and complete the proper *Beaver Removal Documentation Form*, of which copies will be sent to the Wildlife Biologist and Regional Director.

5.4.4.2 Birds

5.4.4.2.1 Gulls

Quabbin Reservoir provides a nighttime roosting site for a variable number of gulls throughout the year. In addition, a small number of gulls will use the reservoir during the day as a loafing and resting area. Herring, ring-billed, and great black-backed gulls are the most common species. Gull numbers begin to increase during the late summer and continue to increase throughout the fall. During winter, numbers can grow substantially and usually reach their peak when all other local bodies of water have frozen but Quabbin remains open. It is not unusual to have as many as 2,500 birds roosting each night. By spring and early summer, most gulls have left the area and returned to their breeding sites along the coast (herring and great black-back) or to interior nesting lakes (ring-billed).

Roosting gulls typically leave the reservoir soon after sunrise and disperse to spend the day feeding at landfills, agricultural areas, large open fields, or at various shopping malls and parking lots. By late afternoon, gulls begin returning to the reservoir to roost for the night.

The Division has been monitoring gull populations at Quabbin since 1990. Gull populations and water quality parameters were studied in the early 1990s. Water quality sampling analysis determined that roosting gulls were responsible for an associated increase in fecal coliform counts. In response to this information, the Division initiated a gull harassment program in 1992. The program has been conducted yearly since and uses a combination of pyrotechnics and boats to harass and move birds away from the CVA. Harassment activities typically begin by October each year. Up to 3 boats are deployed each night to chase and harass gulls that are present within the gull harassment zone (**Figure 4**). Boats are on the water from late afternoon until after sunset. The program is administered by Environmental Quality staff

within the Quabbin section. The labor staff is responsible for operating the boats and firing the pyrotechnics.

Figure 4: Quabbin Reservoir Gull-free Zone

Control efforts during the active harassment period of the program are conducted 7 days/week until the reservoir freezes or birds disperse in the spring. When ice or weather prevents boats from being deployed, harassment occurs from strategically placed personnel on shore.

In addition to the gull harassment program, the Division has participated in efforts to control gulls at landfills. In 1998, the Department of Environmental Protection instituted regulations that required all municipal solid waste landfills to harass and discourage gulls from loafing and feeding at their sites. New landfills must submit a written gull harassment program prior to receiving their operating permit. In conjunction with these regulations, Division staff has assisted landfills in developing harassment plans and also aided landfills in actively harassing gulls.

Activities related to the gull harassment program that will take place during the next 10 years include:

- Make weekly observations of gulls roosting on the reservoir to determine numbers of birds, species distribution, flight paths, and behavior.
- Continue to monitor landfills to assess the effectiveness of harassment programs.
- Continue to investigate and document alternative sources of food for regional gulls, including agricultural areas, composting sites, and wastewater treatment facilities.
- Develop, when and where appropriate, new methods or techniques of harassing or discouraging gulls from critical areas of the reservoir.
- Initiate a comprehensive study of gull movements and biology using satellite telemetry.

5.4.4.2.2 Geese

Resident Canada geese are present at Quabbin Reservoir year round; they will leave the area when the reservoir freezes. In addition, during the fall and winter, migratory geese will also utilize the reservoir. While geese are much fewer in numbers than gulls, they still represent a priority management species and are actively harassed during the bird harassment program.

Since 1999 the Division has conducted a resident goose population control program at Quabbin Reservoir. Each spring efforts are made to locate geese nesting on the reservoir. Once identified, eggs in each nest are treated to prevent hatching. The long-term goal of this program is the gradual reduction in the resident adult goose population. In addition to efforts to locate and treat nests close to the CVA, (**Table 56**), this program now includes an extensive search of all reservoir islands.

Table 56: Number of Canada Goose Nests and Eggs Treated 1999 -2007, to Prevent Hatching

Year	# Nests	# Eggs Treated
1999	8	37
2000	10	37
2001	9	41
2002	7	36
2003	7	36
2004	7	34
2005	3	11
2006	9	43
2007	6	34

5.4.4.2.3 Other Waterfowl

A variety of other waterfowl utilize Quabbin Reservoir at various times during the year. During the spring and summer, there is a relatively small number of resident mallard ducks that nest on islands. During the fall and winter, the number of waterfowl can increase substantially as migrating birds use Quabbin as a rest stop. Ring-necked ducks, common mergansers, common goldeneyes, and other species can all be found on the reservoir during the fall and winter. All species of waterfowl are included in the harassment efforts if they are located within the bird harassment zone.

5.4.4.3 Burrowing Animals

The burrowing activity of certain wildlife species such as woodchucks, moles, and voles can cause damage to the integrity of earthen dams, dikes, and other watershed structures. Woodchucks have been a recurring problem along Winsor Dam in the past few years. Both lethal methods and live-trapping have been used to remove these problem animals. DWSP is working to develop long-term management techniques to discourage reoccupation.

5.4.4.4 White-Tailed Deer

White-tailed deer populations are increasing in most of the northeast. There is growing concern about these increasing populations and their impact on natural resources (Healy 1997a, Healy 1997b, Alverson and Walker 1999, McShea and Rappole 1997). Deer populations within Massachusetts are increasing in the central and eastern part of the state (MassWildlife, pers. comm.). White-tailed deer can thrive in suburban environments where there is abundant food, few predators, and enough wooded areas to provide cover. Coupled with expanding deer populations is increased fragmentation of the landscape that can isolate these wooded reserves and in many cases prevent people from effectively hunting white-tailed deer populations. Even in areas where hunting is feasible, there is growing concern that both hunter interest and hunter recruitment is declining. In many situations, these circumstances can lead to overabundant deer densities.

Overabundant deer populations can influence and affect the abundance of woody species (Walker and Alverson 1997). In addition, intensive deer browse may cause problems in regenerating particular species such as oak. When deer populations are protected for many years and sustained at high densities, forest structure may be altered completely, resulting in park-like stands with grass or ferns dominating the understory (Walker and Alverson 1997). Situations like this were documented on the Quabbin Reservation and in the Alleghany National Forest in northwest Pennsylvania (Walker and Alverson 1997). In response to growing concerns about the lack of forest regeneration and the absence of an understory layer within large portions of Quabbin Reservation, the area was opened to limited, controlled public deer hunting in 1991. Hunting has been conducted on the reservation each year since.

The controlled hunts constituted only one component of a comprehensive 1991 White-tailed Deer Impact Management Plan for the reservation that also included the use of electrified fencing and various changes in the Division's land management program. That plan called for six years of controlled hunting, followed by a major review and re-evaluation of the program. That review was conducted in the spring of 1997 when two reports (*Quabbin Regeneration: Summary Report 1988-97* and *Quabbin Reservation White-tailed Deer Impact Management Program: Results and Evaluation 1991-1996*) were issued by the Division. Also at that time, recommendations for the next phase of the program were issued in the document *Quabbin Reservation White-tailed Deer Impact Management Program: Summary Report and Proposal 1997*. Those recommendations called for a continuation of the controlled hunting program with several changes proposed to make the program more efficient.

The driving force behind the deer reduction program has always been to reduce the impacts of deer browsing to a level that allows and promotes the development of a healthy, resilient, diverse forest that can adequately and continuously protect water quality. Major components of the deer population reduction program were to: 1.) Reduce population densities; and 2.) Maintain those densities at a level that allows for the continued growth and regeneration of forest tree species.

After several years of controlled hunts, substantial reductions in deer population densities were achieved in all hunt areas, and the Division has been in the maintenance phase of its program for several years. The maintenance phase of the program is essential for maintaining relatively stable deer population levels and eliminating potentially large swings in deer densities that could occur if hunting were stopped for an extended period of time. In the absence of regular hunting mortality, deer populations at lower densities that have little natural mortality and an increasing food supply would expand and could jeopardize the forest regeneration progress made to date. In 2000, a five-year plan was developed that outlined proposed activities for the next five years. In 2004, a second 5-year plan was written, and it outlined the program's goals and plans through 2009 (Clark 2004).

Since 1991, Quabbin deer populations have been decreased substantially through the annual managed hunts, and the forest has responded tremendously. Regeneration surveys conducted during 2004 indicate that the number of tree stems/acre has increased from 910 in 1989 to 4,532 in 2004 (a 400% increase). Tree species diversity also continues to increase, and although white pine and black birch dominate the understory, more maple, oak, and hemlock trees are present.

Deer hunting on Quabbin Reservation is limited to a 4-day managed hunt, with access strictly controlled through a check-in/check-out procedure. Participating hunters are required to attend an orientation session every 6 years and follow specific rules and regulations to ensure hunter safety and protect water quality. Since 1991, over 4,000 deer have been harvested from Quabbin Reservation by approximately 19,000 hunters (**Table 57**). Since 1991, several administrative changes have been made to the hunt including allowing car scouting prior to the hunt, instituting a 5-block rotation, and defining antlerless deer killed at Quabbin as "bonus" (not counting towards the state-wide bag limits).

Table 57: Deer Harvest and Hunter Success Rate, 1991 to 2005

YEAR	TOTAL DEER	% FEMALE	% MALE	% A/L[1]	DEER/Mi^2 (killed)	# HUNTERS	HUNTER SUCCESS[2]	Mi^2 HUNTED
1991	575	60.3	39.7	71.8	40.9	855	67.3	14.1
1992	724	54.0	46.0	60.5	21.7	1971	36.7	33.4
1993	474	62.0	38.0	67.1	9.5	2168	21.9	49.7
1994	673	59.9	40.1	68.9	10.7	2118	31.6	63.1
1995	284	64.8	35.2	74.3	4.7	1508	18.8	60.9
1996	129	58.1	41.9	67.4	2.0	1213	10.6	63.1
1997	293	62.1	37.9	73.4	4.8	1207	24.3	63.1
1998	123	57.7	42.3	65.9	2.3	1099	11.2	55.8
1999	112	39.3	60.7	51.8	1.8	1192	9.4	63.1
2000	106	47.2	52.8	55.7	1.7	818	13.0	49.1
2001	101	51.5	48.5	58.4	1.9	855	11.8	52.0
2002	153	48.4	51.6	64.1	3.0	967	15.8	50.2
2003	306	69.0	31.0	83.7	6.9	938	32.6	44.2
2004	167	47.9	52.1	58.7	3.0	1259	13.3	55.8
2005	117	53.0	47.0	65.0	1.8	1071	10.9	49.0
Total	**4337**	**55.7**	**44.3**	**65.8**		**19,239**	**21.9**	**-**

[1] A/L: antlerless; females and young males with antlers less than 3 inches long.
[2] Hunter success is the number of deer taken per 100 hunters. Some hunters took more than one deer, so these figures slightly overestimate the proportion of successful hunters

5.4.4.5 Moose

5.4.4.5.1 General

Moose are North America's largest wild animal. An average adult moose weighs around 1,000 pounds and stands 6 feet at the shoulder. Moose and their ancestors originated in Siberia and made their way to North America across the Bering land bridge. At the time of European settlement, moose were distributed from Alaska, across Canada into the northern United States from North Dakota east to Pennsylvania and all of New England, including Massachusetts. Moose also extended down the Rocky Mountains in the West. Temperature was probably the limiting factor in the southern distribution of moose in North America. Winter stress typically occurs when temperatures exceed 23°F and summer stress when temperatures are >59°F (Franzmann and Schwartz 1997).

Moose were extirpated from Massachusetts by the early to mid-1800s (Peek and Morris 1998, Veccillio et al., 1993). A small number of moose escaped from a game preserve in Berskshire County around 1911 and may have persisted for several years (Veccillio et al., 1993). Most sightings during the next 50 years were probably northern vagrants. Since the late 1980s, the number of moose sightings has increased greatly (Peek and Morris 1998). In 1998, the state's moose population was estimated as at least 75 animals including cows with calves (Peek and Morris 1998). Current estimates of moose populations in Massachusetts are around 700 animals (MassWildlife pers. Comm.). Reasons for the increase in moose populations include the absence of predators, reversion of farms to forested areas, legal protection, increased wetlands from expanding beaver populations, and larger forest openings (Franzmann and Schwartz 1997).

Moose populations continue to expand in Massachusetts. Division land within the Quabbin watershed probably functions as a core habitat for moose populations given its large size and diversity of habitats. Moose populations in the state suffer relatively little natural or human caused mortality. Black bears are the only potential predator of moose and are limited to killing young calves. There are approximately 2000 black bears in Massachusetts, and most of them are located west of the Connecticut River. As a result, current bear populations are not capable of limiting moose populations. The main source of moose mortality is most likely from interactions with people. In 1997, 12 moose were killed on roads, 4 nuisance animals were destroyed, and 4 were immobilized and relocated (Peek and Morris 1998). It is likely that moose/vehicle collisions will continue to rise as moose populations expand. Because moose/car collisions are extremely dangerous for both humans and moose it has been suggested that moose are incompatible with an urbanized state such as Massachusetts, and the public's tolerance of moose is limited (Peek and Morris 1998, Veccillio et al., 1993).

5.4.4.5.2 Moose and Vegetation

Moose are primarily browsers and feed on the leaves, buds, and twigs of a variety of tree and shrub species. An adult moose can consume 40-60 pounds of browse daily (Snyder 2001). During the summer, moose spend time in lakes and ponds feeding on aquatic plants.

A good deal of work has been done assessing the impact of moose on boreal forest ecosystems (Danell et al., 1991, Edenius 1994, Angelstam et al., 2000, Connor et al., 2000, McLaren et al., 2000, Brandner et al., 1990, McInnes et al., 1992). There exists little if any information on the impact of moose in the southern portion of their range. While boreal ecosystems are relatively simple in terms of species diversity and structure, forests in Massachusetts are much more complex in both composition and processes. While information regarding moose in boreal ecosystems is important and insightful, it does not necessarily represent moose in mixed hardwood/softwood forests.

In Europe, moose were shown to have negative impacts on the quantity and quality of Scots pine (Angelstam et al., 2000). Moose density was found to be the contributing factor affecting the amount of moose related damage (Angelstam et al., 2000). A study in a Newfoundland park suggested that moose have changed species composition and influenced forest succession (Conner et al., 2000). Hunting has been prohibited in the park since 1974, and natural predation by black bears has not had an impact on the moose population (Conner et al., 2000). Several studies have examined the interaction of moose and Balsam fir, a preferred winter food of moose. In order to successfully regenerate Balsam fir in Newfoundland, McLaren et al., (2000) had to maintain high hunter harvest until trees were >3m in height. McLaren et al., (2000) concluded that since wolves were extirpated from Newfoundland, hunting has been the only option to reduce moose populations. McInnes et al., (1992) concluded that moose in the boreal forests of Michigan prevented saplings of preferred species from growing into the canopy. Further, it appeared that browsing by moose influenced the long-term structure and dynamics of the boreal forest ecosystem (McInnes et al., 1992).

Compared to the relatively simple ecosystem of the boreal forest, Massachusetts's forests are comprised of a diversity of hardwood and softwood species. The relative impact of moose on any particular species is unknown. However, there is substantial evidence linking overabundant deer populations in hardwood forests with negative environmental impacts (McShea et al., 1997). If moose populations continue to expand, the potential exists for moose to impact forest ecosystem structure and function. Localized browsing damage has already anecdotally been noted, particularly during winter weather when moose mobility becomes hampered and browse pressure becomes locally intense.

5.4.4.5.3 Monitoring Moose Populations

Because moose populations are expanding in Massachusetts and little is known about the potential impacts of moose on forest ecosystems, it is important to monitor moose populations over time to gather as much information as possible. The Division has taken an active role in a variety of moose research or moose related topics, including:

1. In April 2002, the Division began a moose monitoring program on the Ware River watershed (see **Estimating Relative Abundance of Moose on MDC Property: Results of the 2002 Ware River Pilot Project** report). Monitoring has continued yearly since 2002, and will continue into the future. The same monitoring program was initiated at Quabbin in 2003 on the Prescott Peninsula. However, staff shortages have prevented the study from being done since. Efforts will be made to restart the study during 2008.
2. The Division contributed $20,000 to funding a cooperative study of moose in Massachusetts. The study, being conducted by UMass and the USGS Massachusetts Cooperative Fish & Wildlife Research Unit, has several moose tagged with GPS collars to closely follow their movements.
3. An aerial infra-red survey of Quabbin Reservation was conducted during the spring of 2007 to identify deer and moose. The survey produced a known minimum number of animals during one point in time. While initial results were encouraging, time constraints prevented the contractor from adequately completing the survey. A new survey is scheduled for fall 2007.
4. Division staff have provided testimony at Senate sub-committee meetings discussing the potential impacts of moose on the landscape and encouraging legislators to modify existing laws to allow moose to become a regulated game species.
5. During the 2006 Quabbin deer hunt, hunters were given moose survey cards to report sightings. Hunters who saw moose during the hunt filled out the survey card and reported their sightings to Division biologists to record on a topographic map. Sightings were used to estimate minimum population estimates. Surveys will continue during future Quabbin hunts.

5.5 Management and Protection of Biological Diversity

Biodiversity can be defined as the diversity of life in all its forms and at all levels of organization (Hunter, 1999). This definition looks beyond simple species diversity to include genetic and ecosystem diversity as well. Setting management goals for maintaining biodiversity is inherently difficult for a variety of reasons. In most cases natural resource managers are responsible for managing biodiversity without a complete understanding of all the elements of biodiversity that may exist within the lands that they manage. For example, approximately 1.7 million species have been described globally, although estimates of the total number of species range from 10-100 million (Hunter, 1999). The local knowledge of species, habitat, and community dynamics is improving, but is still far from complete.

Incorporating the promotion of biodiversity in management activities requires management decisions to be made with a watershed, landscape, or larger regional perspective. Throughout the agency's tenure, DWSP management activities have incorporated specific practices that maintain or enhance biodiversity at the forest stand level (i.e., saving wildlife trees, buffering wetlands, protecting rare communities, etc.). In recent years, DWSP has made more deliberate efforts to further incorporate the landscape perspective in its efforts to support biological diversity. The "green" certification process (see sections 1.5.2 and 5.5.2.1.2) resulted in specific conditions for management requiring this larger-scale perspective in management. For example, certification conditions included the requirement to develop ecoregional plans as background guidance for local site plans (see section 1.5.3) and the recommendation that the state identify large and small areas permanently reserved from management, in order to allow the development of late seral forest conditions in significant blocks across the state (see sections 1.5.4 and 5.5.2.1).

Hunter (1999) describes only 2 real goals when planning for biodiversity: 1) Maintain the biodiversity of ecosystems that are in a reasonably natural condition and 2) Restore the biodiversity of ecosystems that have been degraded. DWSP's goals for biodiversity focus on maintaining or enhancing natural ecosystems across the watersheds. DWSP recognizes that its greatest contribution to regional and local biodiversity is protecting significant areas of land from development and maintaining those lands in forest or other natural cover. DWSP's primary management activity on these lands is creating small openings in the forest to stimulate regeneration and diversify species and age composition. These activities maintain forest cover while mimicking small-scale disturbances that occur naturally.

5.5.1 Biodiversity Mandate: Programmatic and Regulatory Framework

In 1973, Congress passed the Endangered Species Act to provide federal protection for 292 declining species, and began to legally define the national commitment to maintaining biodiversity in the process. The ESA specifically protected 27 plant and animal species in Massachusetts, and provided both the impetus and funding to restore popular species such as the Peregrine Falcon and the Bald Eagle in the state. Subsequent to the passage of the ESA, Massachusetts has added additional statewide legal protection for biodiversity. Both Chapter 131 (the Wetlands Protection Act) and Chapter 132 (the Forest Cutting Practices Act) require regulatory bodies to consider impacts on habitat and species during proposed development or management activities. In 1990, Massachusetts passed its own Endangered Species Act, providing protection currently for 424 plant and animal species. This act provides regulatory protection for significant habitats of the listed species, as well as direct protection for the species.

In recent years, the protection of biodiversity has become a high priority for Massachusetts state agencies. Massachusetts is a diverse environment that currently supports at least 15,000 visible (i.e., macroscopic) native species of plants and animals (including about 12,000 insects). MassWildlife (previously the Division of Fisheries and Wildlife) currently maintains the Natural Heritage and Endangered Species Program, the goal of which is to protect the state's native biological diversity. MassWildlife also recently launched the "Biodiversity Initiative," in order to coordinate two new programs that were created by the

1996 Open Space Bond Bill (Chapter 15, Acts of 1996). These programs include the Ecological Restoration Program and the Upland Habitat Management Program. The Ecological Restoration Program's major goal is to "focus future restoration action on the fundamental problems threatening biodiversity, including the restoration of natural processes and native community composition." To achieve this goal, the Ecological Restoration Program intends to follow the following strategies:

- Conserve species before they become rare by protecting their habitat.
- Restore natural processes that sustain biodiversity at key sites.
- Limit invasion by exotic or invasive species.
- Replicate natural processes, where they cannot be maintained or restored, at appropriate times, places, and in justifiable quantities.
- Consider species reintroduction only when species' requirements and causes of extirpation are sufficiently understood, and carefully consider the costs and benefits.

The Natural Heritage Program, in conjunction with the Massachusetts Chapter of The Nature Conservancy published "Our Irreplaceable Heritage: Protecting Biodiversity in Massachusetts" in 1998. This document outlines a Biodiversity Protection Strategy that includes the following:

- Encourage all conservation agencies, land trusts, municipalities, and not-for-profit conservation organizations to increase the importance given to and financial support for the conservation of uncommon and under protected components of biodiversity.
- Educate landowners about maintaining and restoring certain natural processes and minimizing disturbance.
- Aid land managers in implementing land management techniques that mimic natural processes where they cannot be maintained or restored.
- Strive to achieve an equitable distribution of biologically viable conservation lands at all topographic elevations and across all ecoregions.
- Take action to conserve natural communities and species that have experienced tremendous loss or are under considerable threat.
- Focus attention on natural communities and common or rare species that are underprotected.

The April 2000 "The State of Our Environment" from the Executive Office of Environmental Affairs (EOEA, now the Executive Office of Energy and Environmental Affairs, EOEEA), acknowledges the link between human needs and healthy, thriving natural communities. EOEEA identifies loss of habitat through development and invasive species as the two most distinct threats to maintaining natural diversity in Massachusetts, and further commits to preserving biodiversity through the identification and protection of critical habitats and the creation of bioreserves that include central cores of public land.

As stated in Section 4.5, DWSP's principal goals for maintaining biodiversity on its Quabbin holdings are to retain most of these lands in a forested condition, to identify and provide habitat for the protection of uncommon and rare flora and fauna, and to eliminate and prevent the spread of non-native invasive

species. DWSP also seeks to provide the range of seral stages from early successional habitat through unmanaged mature forest across its total holdings.

5.5.2 Massachusetts Biodiversity Objectives and Accomplishments: 1995-2007

The maintenance of biological diversity across the Commonwealth of Massachusetts has been a priority among state agencies for many decades, although the term "biodiversity" has been popularized only since the mid-1980s. In 1988, E.O. Wilson edited and published Biodiversity, a National Academy Press publication, and the term has been in popular use since that time. Preserving our "natural heritage" carries similar objectives as the conservation of biological diversity and programs devoted to natural heritage have been developed in every state in the U.S., including the Natural Heritage and Endangered Species Program (NHESP) in Massachusetts, a component of the Division of Fisheries and Wildlife. The Massachusetts NHESP, in conjunction with the Executive Office of Environmental Affairs and the state land agencies, has been at the forefront in developing programs to support the conservation of biodiversity.

5.5.2.1 Statewide Biodiversity Initiatives

5.5.2.1.1 BioMap

The BioMap was an initiative of the EOEEA to utilize existing and new databases of rare plants, animals, and natural communities collected since 1980 to produce a guide for land conservation efforts in the state that would more efficiently support and protection existing and potential sources of biodiversity. The BioMap report, published in 2001, provides the methods used in the assessment of 7,000 site-specific records within 13 ecoregions in Massachusetts which generated priority areas for conservation efforts. Within each ecoregion, "core habitat" is identified as well as areas within that core that are currently protected versus unprotected. A full text of the BioMap as well as technical guides to the process are available through NHESP and/or online at http://www.mass.gov/dfwele/dfw/nhesp/nhbiomap.htm .

5.5.2.1.2 Green Certification

At the beginning of the previous management period for the Quabbin Reservoir watershed, the Division sought "green certification" from the international Forest Stewardship Council, through the FSC-approved SmartWood program of assessment. The 1997 certification of Quabbin Reservoir watershed forestry practices was the first third-party, "green" certification of public lands management in North America. As the Quabbin certification approached its five-year renewal date, the Executive Office of Environmental Affairs (EOEA, now EOEEA) decided to pursue a broader certification audit. On May 11, 2004, *all* state forest lands in Massachusetts became "green" certified.

Certification provides third-party review and auditing of forest management practices for the long-term sustainability of their relationship to the environment and to the regional human economy. The Massachusetts state lands certification was granted by Scientific Certification Systems, an independent, third-party certification body accredited by FSC. Certified lands in Massachusetts are managed by different agencies of the EOEEA, including the Division of State Parks and Recreation (285,000 acres), the Division of Fisheries and Wildlife (110,000 acres), and the Division of Water Supply Protection (104,000 acres). With this certification, Massachusetts becomes the first state in which multiple forest management agencies have joined forces to earn certification of all of the publicly managed state forestland. Certification is an endorsement, but conditions for improvements in management practices must be attained within a five-year period for this endorsement to remain current and valid. The full MA certification report, including the details of these conditions is available online, at www.mass.gov/envir/forest/default.htm.

5.5.2.1.3 EOEEA Reserve Initiative

As a result of the green certification process, EOEEA also initiated an effort to identify large areas across the state land holdings that would be permanently set aside from commercial timber harvesting in order to allow the development of habitat conditions that may not develop under active management. These large reserves were identified through a scientific process worked out in conjunction with science staff from The Nature Conservancy and intend to provide conservation of habitat conditions determined to be high priorities at the landscape scale of analysis. Nine reserves totaling in excess of 50,000 acres were proposed by EOEEA in 2005 and adopted in 2006. A full description of the process and these proposed reserves is available online at www.mass.gov/envir/forest/pdf/whatare_forestreserves.pdf.

5.5.2.2 Quabbin Biodiversity Initiatives

5.5.2.2.1 Identification of Rare, Uncommon, and Exemplary Communities

The Quabbin watershed harbors a wide array of unique natural communities. Some of the communities are rare on a regional or global level. In response to a recommendation by the FSC forest certification auditor that the biological diversity at Quabbin should be better characterized, the University of Massachusetts Department of Natural Resources Conservation, under the primary direction of Associate Professor Kevin McGarigal, from 1997 to 2000, assessed the watershed for rare, uncommon, and exemplary natural communities. In a September, 2000 report entitled, *Rare, Uncommon, and Exemplary Natural Communities of Quabbin Watershed"*, the purpose of this study is described: "to identify, classify, and describe the rare, unique, and exemplary natural communities in the Quabbin watershed area of Massachusetts and to provide recommendations for their management". The report identifies 22 rare communities in the Quabbin watershed and describes these in detail and is available through Natural Resources staff at Quabbin.

5.5.2.2.2 Protection of Rare Species

The Division provides extensive protection for known populations of rare, endangered, or uncommon species, primarily through protection of their habitats. Division staff record new occurrences as they are discovered, and track changes in existing populations. The Division works extensively with the DFW Natural Heritage and Endangered Species Program to protect these species, and through a joint collaboration between DCR and NHESP, recently helped to produce updated Forestry Conservation Management Practices for specific species that may be encountered during harvesting operations.

The following were among the protection efforts initiated by the Division during the previous management period:

1. Identification and mapping of populations of rare plant species, first through a two-year contract with the University of Massachusetts Biology Department, and later through annual visits by professional botanists to survey habitats predicted to contain rare species. From 1995 to the present, at least 15 new populations of rare or endangered species were identified through this survey work (see section 2.6.2.2), including a 2007 discovery of *Asclepias purpurascens L.*, the threatened Purple Milkweed.
2. On at least two of the sites on which populations of rare plant species were identified, manual removal of invasive plant species threatening these populations was performed by Natural Resources staff.
3. New Wildlife Conservation Management Practices (WCMPs) for the protection of habitats and rare species during harvesting operations were developed with NHESP for Blanding's turtle, eastern box turtle, wood turtle, spotted turtle, four-toed salamander, mole salamanders, and common loon. Discussions also focused on identifying critical habitat conditions surrounding vernal pools, and forestry practices to maintain these.

5.5.3 Areas with Special Management Restrictions and Small Reserves

The 1972 *Quabbin Reservoir Watershed Land Management Plan* delineated areas on which conventional forest management practices were either impractical or otherwise undesirable. That plan included 3,360 acres in "Aesthetic Areas" and 3,200 acres of "Protection Areas", which included islands, rock quarries, caves, rock outcrops, hill top views, cellar holes, mill sites, exceptional forests or individual trees, and areas that have been undisturbed for the past 100-150 years. The "Protection Areas" also included 1,350 acres in the Cadwell Creek watershed, a control area for a watershed study done by the University of Massachusetts. While the Division had not planned cutting in the "Protection Areas", commercial forest management in the "Aesthetic Areas" was allowed if special logging techniques were used. The plan also included 1,440 acres in "Wildlife Wetland Areas" (chiefly beaver flowages), where no cutting was planned.

In the 1986 *Quabbin Forest and Wildlife Management Plan*, 7,600 acres were designated in the "Protection Zone". This zone included steep, rocky, or extremely wet sites; exceptional, rare, or endangered plant communities, or wildlife habitat; and significant cultural resource sites. No forest management was permitted in this zone.

This Section updates the concept of areas where special management restrictions apply. As the Division continues to refine its analysis of the watershed protection provided by the lands under its control, some refinements in the restrictions have been made. For instance, efforts to maintain an understory (for the reasons cited throughout the plan) seem even more critical in riparian zones than in areas that are distant from tributaries or the shoreline. While riparian areas have traditionally been untreated, understory maintenance will be a priority for this decade, and will include such practices as planting, single tree selection harvesting, and non-harvest silviculture to stimulate understory growth.

Table 58 lists the areas with special management restrictions as they stand currently. The recent Forest Stewardship Council re-certification of Quabbin's forest management practices, provided by Scientific Certification Systems, acknowledged the long-standing identification and treatment of these areas by the Division as meeting the certification criteria for the designation of "ecosystem reserves". Specifically, the certification report states:

> [DCR] has submitted adequate information to determine that they have reserved a substantial portion of their ownership (>15%) as natural areas or unmanaged lands. Furthermore, the silvicultural strategy employed on [DCR] lands assures that old forest conditions will be encouraged within managed areas of the forest. This agency is protecting a substantial amount of their ownership, and they have done extensive inventories for rare species and communities on their ownership. (SCS 2004)

Included in the lands in **Table 58** are two major categories:

- Areas with uncommon, rare, or potentially rare resources.
- Areas where commercial forest management is impractical.

The first category includes areas such as uncommon forest communities, habitats containing rare, endangered, or threatened plant or animal species, and historic/prehistoric sites. Examples of these areas include pitch pine/scrub oak communities, diverse or unique regions designated as Natural Areas, and cellar holes and Native American encampments and work sites. The delineation of each area may also designate an appropriate buffer zone around the resource.

The second category includes commonly occurring but fragile areas such as bogs, forested wetlands, marshes, wet meadows, vernal pools, areas with fragile wetland soils, and slopes greater than 30%. There may be rare plants, animals, or communities within these sites as well, and overlap of the two categories

of restrictions is not uncommon. For example, steep talus slopes are generally impractical to operate with timber harvesting equipment and often harbor rare or uncommon plants as well.

Approximately 10,000 acres of DWSP lands at Quabbin were classified in the 1995-2004 Land Management Plan as "Areas with Special Management Restrictions". These areas include large blocks of land such as the 3,716 acres of reservoir islands and two blocks in excess of 1,000 acres each in Quabbin Park and adjacent to Pottapaug Pond. All identified wetlands and steep slopes are included, some of which are contiguous areas of several hundred acres (e.g., the steep Pelham shoreline, or the wetlands along the East Branch of Fever Brook). In addition, many small areas have been included, representing sensitive resources and buffers around historic and rare wildlife habitat areas. For example, Division and University of Massachusetts staffs have mapped, from aerial photos, more than 500 potentially viable vernal pools across the Quabbin watershed.

In addition to these previously designated lands, the Division has been gradually mapping areas that are impractical to manage for a combination of reasons. For example, some potentially manageable land is enclosed by wetlands or adjacent rare species habitat in such a way that the land will not be managed. These lands will be excluded from the total acreage considered to be under active forest management. Based on a similar approach on the Ware River watershed, it is expected that once the mapping process has been completed, the acreage that is identified as reserved from active management will total approximately 25-30% of the total DWSP holding at Quabbin. Therefore, approximately 15,000 to 18,000 acres on this watershed will grow and develop without timber harvesting. There may still be efforts to manage such influences as invasive species, herbivore populations, and fire on these properties, but active commercial silviculture is not planned for these areas.

Table 58: Areas with Special Management Restrictions within the Quabbin Reservoir Watershed

Area	Acres	Restrictions/Practices
Islands	3,674	No management
Steep slopes	1,712	No management
Wetlands	2,272	No management except limited beaver control (see beaver policy, Section 4.4.4.1)
Rare and endangered species habitats	NA	Subject to restrictions upon advice of Natural Heritage and Endangered Species Program
Quabbin Park (western portions) acres	1,058	Limited management including tree planting, non-commercial regeneration cuts, and roadside salvage cutting
Pottapaug Natural Area	1,183	Restricted by designation as a Natural Area, in 1991, no commercial management.
Areas where access is precluded by physical or regulatory barriers	Mapping in progress	No active commercial management; control of herbivores, invasive species, fire may occur
Areas of Historic, Cultural, or Natural Significance	NA	Varies from no management to selective restoration and maintenance

Areas that have been set aside for the reasons mentioned above also can function, on a long- or short-term basis, as areas from which background measurements can be taken for comparison to areas that are directly under management. The Division will retain this function, and will regularly reevaluate the sufficiency of current "restricted" areas for establishing background information.

GIS analysis has provided some preliminary information on this topic. For instance, of the 12 common forest types occurring on the Quabbin Continuous Forest Inventory plots, six are also represented on CFI plots that fall within the "restricted" areas (most of the "missing" types are generally uncommon, such as red spruce, larch, or pitch pine.) Each of the five Division soil types (see Section 2.2.6.) is well-represented within the "restricted" areas. The Pottapaug Natural Area (**Figure 23**) was added to this category to address the public interest in a block of accessible forest that was allowed to grow and change without silvicultural intervention. The area was chosen because it offered a wide variety of forest types and wildlife habitats but was hydrologically removed from the Shaft 12 intake and sheltered from typical, south-easterly hurricane winds. The details of long-term management of this area, including fire and invasive species response, are being developed (e.g., the decision to let a wildfire burn rests in the hands of the fire chief of the town, not with the Division).

Figure 23: Pottapaug Natural Area

5.5.4 Management for Special Conditions

5.5.4.1 Primary Forests

5.5.4.1.1 Definition and Significance

Primary Forest or "primitive woodlands" are areas that have always been in a forest condition or cover. These lands were not cleared for crops or pasture, and instead managed for forest products, such as timber for barns and houses and for firewood. The location of primary forest comes from crude maps provided by the Harvard Forest that were made for tax purposes by town governments in Massachusetts in 1830, at the height of agricultural clearing. The working assumption is that because these woodlands had not been cleared by the height of the land clearing period, they likely have been woodlands throughout history. The locations of Quabbin's Primary Forest were determined from these maps. These forests are usually located in the uplands, on steep and/or on rocky ledge soils or wetlands unsuitable for even pasture. Cultural features such as stone and wire fences are absent and often late successional species such as hemlock, beech and tupelo are present. Sometimes the maps were found to be incorrect, as to the extent of the primary forest, because field checks found stone fences and pasture type trees even on steep and rough land with stony soils and exposed ledge. In a few cases primary forest were located on mostly level uplands and suitable for quality pasture, but for some reason stayed in forest. Part of the significance of primary forest is that many organisms from the original forest may still be present and may be important in determining long-term sustainability of forest ecosystem integrity.

5.5.4.1.2 Management Practices in Primary Forests

Since most of the primary forest at Quabbin is either on steep slopes or wetlands or on sites of very low productivity, it has not been and likely will not be actively managed. Primary forest located on productive and accessible areas will be managed using multi-aged silvicultural methods. The proposed management would allow for older age classes to occupy more then 1/3 of the area. Cutting cycles would vary from 30-50 years and require 60-100 years to develop multiple age classes where only one now exists. At the stand level this management would be designed to promote and maintain structural elements, similar to those found in old growth stands. Structural targets are 12 or more trees/acre >20" DBH and dead snags and live cavity targets are 2 trees/acre > 12" DBH, 3 trees/acre >15" DBH, 1 tree/acre > 18" DBH and 1 tree/acre > 20" DBH. Primary forest occupies approximately 10-15% of the overall forest.

5.5.4.2 Late Seral Forest Conditions

5.5.4.2.1 Value of Late Seral Forest Conditions

The late seral stands discussed here are often the second forest stand to occupy the site since the land was abandoned for agricultural purposes such as pasture or tillage. These stands are often on productive soils and with species well suited to the site. Most of these stands regenerated between the Civil War and World War I. They are not of great age but are of large diameter, exceptionally tall, and of high quality. Their location varies from very accessible to remote and consequently spread across the landscape. Their importance is derived from both their scattered presence on the land and their potential to provide old growth attributes at an early age. They are often bordered by primary forest or stone walls and agricultural border trees of great size, that often have large cavities. Unlike primary forest, which tends to be on less productive sites, these late seral stands are on highly productive sites and consequently of high stocking (density). They came about during a time with few or no large herbivores or invasive species, diseases and insects. Air pollution was minimal during most of their development. The plant community and the processes that assist its growth and development were intact. These exceptional conditions for tree and stand development may be impossible to duplicate in the future, but the Division will try to take advantage of the exceptionally good conditions afforded by these stands.

5.5.4.2.2 Management Practices to Produce and Sustain Late Seral Forest Conditions

Management of these stands will promote regeneration of similar species, maintain vigor of the overstory and allow for structural conditions similar to old growth. The selection system would be used employing single tree and small group removals and conducted every 30-50 years. Structural targets would be 17 trees/acre > 20" DBH and dead snag and live cavity tree targets would be 3 trees/acre > 14" DBH, 2 trees/acre > 16" DBH, 1 tree/acre > 20" DBH, and 1 tree/acre > 24" DBH. Late seral stands would occupy up to 15% of the forest.

5.5.4.3 Early Successional Forest Habitat

5.5.4.3.1 Importance of Early Successional Forest Habitat

Broad changes in land use have dramatically impacted the number, type, and extent of open lands within the watershed. Early successional habitat was a major component in the landscape prior to European settlement. Evidence suggests that grasslands existed in the Northeast before Europeans arrived, and grassland birds have been a component of avian diversity for a long time (Dettmers and Rosenberg 2000). Beaver activity, wildfires, windstorms, and fires set by Native Americans generated early successional habitat. By the 1800s grasslands were even more abundant in the northeast as agricultural land dominated

the landscape. Since the mid-1800s, the amount of grasslands and open fields has decreased dramatically, causing a similar decrease in many species of plants and animals that depend on open habitat. As farms were abandoned, the open fields and meadows were left undisturbed. Without frequent disturbance such as mowing, burning, or grazing, grasslands gradually revert back to forest. Some grassland species, such as the loggerhead shrike and regal fritillary butterfly, have been extirpated from Massachusetts as their preferred habitat has declined below a minimum threshold.

Recent population trends for grassland dependent species show disturbing declines. Bobolinks and grasshopper sparrows have declined 38 and 69 percent, respectively in the last 25 years. Partners in Flight, a national conservation organization, has identified Neotropical migratory bird species of concern in Massachusetts. These species have a high perceived vulnerability (they may or may not be state or federally listed) and are critical to maintaining avifauna diversity in the state. Priority species include Henslow's sparrows, upland sandpipers, grasshopper sparrows, and bobolinks. These species are all associated with grassland habitat. As farmland continues to be abandoned or converted to house lots, the amount of viable open land continues to shrink. The remaining grasslands, particularly large (>100 acres) or clustered fields, are increasingly vital to a variety of wildlife. Eastern meadowlarks, savanna sparrows, eastern bluebirds, and bobolinks use hayfields, meadows, or pastures to forage and raise young. During the fall and winter, fields provide food for migrating sparrows, warblers, larks, and snow buntings. Raptors such as northern harriers, short-eared owls, and American kestrels hunt in fields for small mammals (meadow voles, meadow jumping mice) and insects. White-tailed deer often graze in fields, and foxes will hunt fields for small mammals or rabbits. Finally, butterflies like the monarch, tiger swallowtail, and various fritillaries feed on nectar of grassland wildflowers.

Early successional forested habitat is also in decline in Massachusetts. Evidence suggests that early successional forested habitat was present in sufficient amounts and distributed well enough across the landscape to support long-term populations of early successional birds in the Northeast prior to either European or Native American intervention (Dettmers and Rosenberg 2000). Fire, major weather events, or beaver activity maintained or generated these habitats across the landscape. European and Native American populations increased the amount of early successional habitat in the region. By the mid 1800s, forest cover in New England had dropped from >90% to <50% (Dettmers and Rosenberg 2000). As farms were abandoned during the late 1800s large amounts of early successional habitat became available. Over time these large areas of early successional habitat grew beyond the early seral stages used by early successional species. A survey conducted in 1998 in Massachusetts concluded that only 4 percent of all available timberland was in a seedling-sapling (early-successional) stage (Trani et al., 2001).

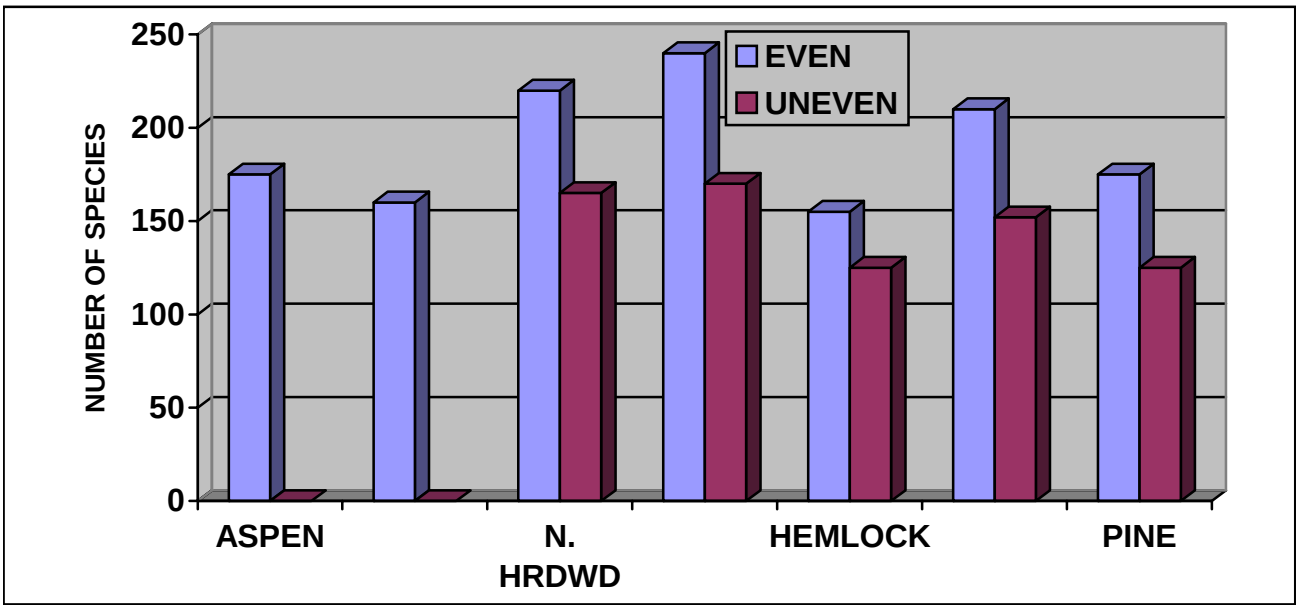
Species dependent on these early successional habitats have been declining since the 1950s as the amount of available habitat continues to shrink (Scanlon 2000). The Partners in Flight "species of concern" list highlights species associated with early successional forested habitat (i.e., blue-winged warbler, Eastern towhee, and prairie warbler). In addition, New England cottontails, bobcat, woodcock, and northern bobwhite have all experienced declines and are dependent on early successional habitat (Hunter et al., 2001, Dessecker and McAuley 2001, Litvaitis 2001). Providing habitat for early successional species involves considerations in both space and time. Early successional habitats are temporary and only support wildlife for 8-15 years. To remain viable, these habitats need to be set back on a regular basis or new areas of early successional habitat need to be created nearby to replace them.

5.5.4.3.2 Management Practices to Maintain Early Successional Forest Habitat

Even-aged forest management is the primary technique used to produce early successional forest stands. This type of silviculture provides the opportunity to regenerate shade-intolerant species such as aspen and birch. The resulting habitat provides distinct foraging and shelter features that are not usually available when uneven-aged management is used (DeGraaf et al., 1992). In addition, even-aged management

appears to have little effect on mature forest species (Thompson and DeGraaf 2001). Even-aged management provides habitat for up to 26% more species than uneven-aged management in similar cover types (DeGraaf et al., 1992) (**Figure24**). Payne and Bryant (1994) state that even-aged management tends to support more wildlife species than uneven-aged management does in northern hardwoods, hemlock, oak-pine, and pine forests of the northeast. Because the current level of tree harvesting within the state is relatively light, widely dispersed, and generally does not provide substantial early-seral habitat, the Division will try to incorporate management techniques geared towards creating a limited amount of this type of habitat, to the extent that this is compatible with water supply protection. In the end, utilizing a range or combination of silvicultural treatments, rather than strict adherence to one, should eventually result in increased use by a wider variety of wildlife species (DeGraaf et al., 1992).

Figure 24: Potential Number of Wildlife Species by Silvicultural System and Cover-type Groups



Wildlife species defined as total number of amphibians, reptiles, birds and mammals using each cover type taken from DeGraaf et al., 1992.
Even-aged: forests containing regeneration, sapling-pole, saw timber, and large saw timber stands of 5 acres or larger.
Uneven-aged: essentially continuous forest canopies and intermixed size and age classes produced by single-tree selection.

Uneven-aged management techniques will be the primary silvicultural approach across the watershed.. For this 10-year management period, the Division's goal for the creation and maintenance of early successional forested and non-forested habitat will be approximately 1% of the manageable land.

Although "clear-cuts" are often associated with even-aged management, there are a variety of even-aged techniques that can be used to accomplish particular management goals. Typically 10-20% of the overstory will be retained in clusters of 5-10 trees scattered across the stand, where creation of these habitats is the objective. An average of 2-3 clusters per acre will be retained. These occasional clumps of trees are an attempt to mimic natural disturbances. Major catastrophic events typically don't completely remove the overstory in a given area, but instead create a patchy effect on the landscape as some trees survive the event. In addition, preserving clumps of trees allows the Division to selectively save valuable mast, den, and nest trees.

In order to create conditions favorable for early successional species, forest openings need to be large enough and placed appropriately to provide enough habitat to sustain viable animal populations over time. The small group openings or single-tree selection that is conducted on a majority of Division land does not provide habitat for species dependent on early successional forest. To the extent that maintaining this habitat is an objective of the Division, larger openings would need to be created on selected areas of the

watershed. Ideally, natural land forms would select the boundaries of these openings and actual acreage would simply work itself out. From a biodiversity perspective bigger tends to be better because larger habitats can more viably sustain animal populations over time. Forest openings of various sizes would be carefully placed within the watershed to ensure adequate water quality protection. Topography, distance to tributaries, soils, stand vigor, and distance to human interface would be considered when planning early successional habitat management. Introducing a limited amount of this type of management provides an opportunity for further study to determine the short and long-term effects of even-aged management on nutrient cycles and water quality parameters.

The Division recognizes the regional importance of these open lands to the diversity of wildlife within the state. Unfortunately, land managers can't rely on nature or natural disturbances to provide this type of habitat. The large amount of land that has been lost to development, coupled with the loss of species and abundance of exotic, invasive species have all combined to alter natural processes. The maintenance of these types of habitats requires active management. Although the Division will continue to manage a majority of its property as a multi-aged, multi-species forest, on particular areas where open habitat exists, or could exist, the Division will manage to maintain or enhance early successional communities.

5.5.4.4 Early Successional Non-Forest Habitat Management Practices

5.5.4.4.1 Field Prioritization

The Division owns a variety of open lands. In most cases, these are lands the Division has traditionally managed in an open condition. Analysis of the distribution, size, and juxtaposition of open lands within the watershed highlights the need for prioritization. Fields will be prioritized based on their size, distance to flowing water, relative isolation, and juxtaposition with other open fields. In general, very small (<2 acres), isolated fields will be abandoned and allowed to naturally regenerate to forest cover. In addition, those fields (or portions of fields) that border reservoir tributaries will also be abandoned and trees allowed to grow. This will provide an adequate forest buffer around flowing streams. Larger fields (>5 acres) that are isolated will be maintained in open condition through various management practices. Large (>20 acres) fields situated near (< 1 mile) or next to other fields will be given top management priority, because these areas offer the most potential for wildlife diversity. Large clusters of open habitat may actually act as one unit, providing habitat for species (northern harrier, upland sandpiper) that require large tracts of open land. These areas will be maintained or enhanced using a variety of management techniques in order to optimize the available habitat.

Following prioritization, those fields not abandoned will receive management to either maintain them in open habitat or to enhance the existing conditions. Management activities will be done by Division personnel, or through a service contract. In all cases, wildlife considerations will be incorporated into the proposed management activities.

The quality of Division grasslands is variable. Encroaching exotic invasive plants are invading some fields. These plants typically crowd out native species and degrade the quality of the existing habitat. Most invasive plants are extremely vigorous and hardy and can be difficult to control. Removal and control of these species is critical to the maintenance of this grassland habitat. Multiflora rose, autumn olive, honeysuckle, and buckthorns have all been found in Division grasslands. Control of invasive plants is addressed in Section 5.5.5.

5.5.4.4.2 Periodic Maintenance Practices for Non-forested Upland Habitat

The Division owns and maintains approximately 60 acres of manicured lawn, located primarily at the administration complex and adjacent to the radio observatory on Prescott Peninsula. These lawns are mowed regularly during the growing season. The Division also owns approximately 165 acres of fields

throughout the watershed. These fields are comprised of a variety of grasses and forbs, and on these fields, wildlife habitat management is an important secondary objective. These fields still require active management in order to maintain them in a grassland condition. However, there are more opportunities to apply various management techniques to enhance the existing habitat.

The following management guidelines for mowing on lands not used for hay production will be followed:

- Limit mowing to every one to three years; this regimen will inhibit woody vegetation while allowing late-blooming wildflowers to develop.
- Mowing should occur after August 1.
- Mower height should be a minimum of 8-10 inches off the ground to provide habitat for small mammals.
- Manage adjacent fields as one unit; multiple contiguous fields should be managed through rotational mowing to provide a diversity of grassland types.

The Division owns several large contiguous grasslands that are potential candidates for other management activities. In addition, some smaller grasslands may also be suited to disturbances other than mowing. Burning grasslands can reduce buildup of dead vegetation, prevent the spread of woody vegetation, release nutrients into the soil, and rejuvenate plant growth. However, burning an area can eliminate some butterflies and moths and the newly burned area may be avoided by some bird species. When feasible and practical, fire management can be a benefit to grassland bird populations and other wildlife usually within a year or two of the burn. If and when the Division conducts fire management, the following guidelines will be followed:

- Burns should be conducted in early spring (mid-March to the end of April) after snowmelt but before bird nesting. Appropriate weather conditions should be considered.
- Grasslands should be burned once every 3-4 years, and if possible, an unburned, adjacent field should be available for nesting birds during the burn year.
- On larger grasslands, only a portion of the area should be burned, if possible, in any given year. Staggering burns allows for the development and availability of a variety of habitat conditions. Not more than 30% of habitat should be burned during any year.

5.5.5 Invasive Plants Management

5.5.5.1 Definitions

"Invasive" plants fall into at least two categories – native or non-native species. Most of the difficulties associated with invasive plants involve plants that are non-native. This is true in part because these non-native "aliens" have been transported out of the ecosystem in which they evolved, and may have escaped specific population-controlling insects and diseases in the process. It is important to point out that not all non-native plants are invasive. Most have been intentionally introduced into agricultural or horticultural environments, and many are unable to reproduce outside of these intensively managed environments. There are, unfortunately, hundreds of others that were introduced either deliberately or accidentally to natural settings and have managed to aggressively force out native plants, raising serious biodiversity issues, and potential threats to water quality protection.

It has taken time for these issues to become apparent. Some of the invasive plant problems on DWSP properties are the result of deliberate plantings of species that effectively addressed other concerns (for instance, planting autumn olive to improve wildlife habitat), but then became invasive. Other invasive species are escapees from landscaping that predates DWSP's acquisition of reservoir properties, including Japanese barberry, common barberry, Japanese knotweed, the buckthorns, Asiatic privets, honeysuckles, and purple loosestrife. In all cases, a plant's "invasiveness" is composed of several defining qualities:

- The plant grows and matures rapidly in abundantly available habitats.
- The plant is capable of producing vast quantities of seed that is easily dispersed by animals, and often can also reproduce vegetatively.
- There are no diseases or pests effectively controlling its reproduction and spread (which generally means there are no close relatives in the habitats it invades).
- The plant does not require intensive management to thrive.

5.5.5.1.1 Federal and Massachusetts Definitions

In February of 1999, President Clinton signed Executive Order 13112, to "prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause"(see: www.invasivespecies.gov/council/nmp.shtml). EO 13112 created a federal Invasive Species Council to "recommend plans and actions at local, tribal, State, regional, and ecosystem-based levels" to address prevention and control of invasives. The first edition of a National Invasive Species Management Plan from this Council was produced in January of 2001, serving as a blueprint for invasive species actions. This plan provides both additional mandate and an overview of the costs and agency responsibilities to begin to gain control over invasives. More recently, the Massachusetts Invasive Plants Working Group produced a methodically developed list of invasive and potentially invasive plants in the Commonwealth, through cooperation among biologists, government staff, non-profits, nurseries, and landscape organizations (see: massnrc.org/MIPAG/index.htm). Strategic recommendations for managing invasive plants in Massachusetts have also been developed by the same group, and are posted on the New England Wild Flower Society's website, at: www.newfs.org/conserve/invasive.htm#strat1. Following the creation of the list of invasive and potentially invasive plants in Massachusetts, the Massachusetts Department of Agricultural Resources, Division of Regulatory and Consumer Services filed legislation to phase these species out of commercial production and use. This legislation passed and became effective on January 1, 2006, effectively phasing out the sale and importation of 140 plant species (see: www.mass.gov/agr/farmproducts/Prohibited_Plant_Index2.htm).

5.5.5.2 Problems Associated with Invasive Plants

The EOEA report "The State of Our Environment" (April, 2000) states that "the two biggest threats to biodiversity in Massachusetts are the destruction and fragmentation of wildlife habitats and the introduction of invasive non-native species." The Nature Conservancy has reported that 42% of the declines of threatened or endangered species in the US are partly or wholly due to the effects of invasive species. Some of these threats are subtle. For instance, when the declining West Virginia White butterfly lays its eggs on the invasive garlic mustard instead of on the usual native mustards, its eggs fail to develop. Other threats are more obvious; for instance, purple loosestrife currently covers an estimated 500,000 acres in northern US and southern Canada, displacing native food sources and threatening to prevent successful nesting in 90% of the wetlands used by breeding waterfowl along the Atlantic and Mississippi flyways. Impacts from invasives on the soil and its faunal community have also been

documented. There is evidence that a Chinese tallow tree is altering nutrient cycling where it invades, causing a decline in the native soil invertebrates as a consequence.

Beyond issues of biodiversity conservation, resilient plant communities are important to watershed management for controlling the erosion of soil and nutrients throughout the range of natural disturbances (e.g., droughts, insect outbreaks, fire, wind, heavy snow and ice). Resilience is dependent upon species and size diversity in the plant community, because disturbances are frequently species and/or size specific. When plants become aggressively invasive, replacing the diverse native flora with monocultures, they increase the susceptibility of the plant community to disturbances. The prevention of forest regeneration by certain aggressive invasives has become a problem on some areas of the watersheds. Around the Quabbin Reservoir, Japanese barberry that was planted on historic home sites has taken advantage of high deer populations (which do not feed on barberry) to colonize and monopolize the understories of significant forest areas. At the Wachusett Reservoir, autumn olive has aggressively occupied open fields, delaying or precluding their return to forest cover. Invasives are often more effective than natives in colonizing disturbed areas, and may overrun young trees that do become established. **Table 59** lists the invasive plants that are present surrounding the Quabbin Reservoir.

Invasion by Japanese barberry on rich, mesic (moist) site

Table 59: Invasive Plants Present on the Quabbin Reservoir Watershed

Common name	Latin name	Habitat
Black locust	*Robinia pseudoacacia*	Edge of forest/field
Norway maple	*Acer plantanoides*	Forest
Oriental bittersweet	*Celastrus orbiculata*	Forest
Japanese barberry	*Berberis thunbergii*	Forest
Common barberry	*Berberis vulgaris*	Forest
Glossy buckthorn	*Frangula alnus*	Forest
Common buckthorn	*Rhamnus cathartica*	Forest
Honeysuckles	*Lonicera sp.*	Open areas
Autumn olive	*Elaeagnus umbellata*	Open areas
Russian olive	*Elaeagnus augustifolia*	Open areas
Multiflora rose	*Rosa multiflora*	Open areas and edges
Goutweed	*Aegopodium podagraria*	Floodplains, riparian areas
Japanese knotweed	*Polygonum cuspidatum*	Riverbanks, wet edges
Purple loosestrife	*Lythrum salicaria*	Wetlands
Garlic mustard	*Alliaria petiolata*	Floodplains, disturbed woodlands, roadsides
Phragmites (common reed)	*Phragmites australis*	Wetlands
Winged euonymus	*Euonymus alata*	Open woods, fields, edge

5.5.5.3 Control and Management Options

All of the features that make a plant invasive also frustrate efforts to control and reverse its expansion. Seed production is generally prolific, and many invasives also reproduce vegetatively. General control requires the removal or killing of mature plants, but also requires that these removals be timed in such a way that they do not result in further reproduction and spread of the plant. Controls are either mechanical

or chemical. Mechanical controls include hand-pulling, girdling or mowing, mulching, tilling, and the use of heat. Chemical control is often more efficient and effective, but carries stronger risks of collateral damage to non-target species, as well as risks of water and soil contamination. Controls need to be designed around the morphology, phenology, and reproductive strategies of specific plants. For example, while prescribed fire will reduce invasions of conifers in native grasslands, it tends to stimulate growth and reproduction of many other invaders.

Recommended controls from various sources in the literature for the treatment of the primary invasive plants found on the Quabbin Reservoir watershed are listed in **Table 60.** The controls listed are not necessarily the methods proposed by the Division to address specific plant invasions. During FY2008, a Division-wide invasive plants plan will be developed that will include mapping and inventory methods, a strategy for detecting and eliminating new invasions, and the prioritization of treatments and controls for existing populations. In addition, the Division will hire two seasonal staff in the summer of 2007 to assist with invasive plant control.

Table 60: Major Invasive Plants on Quabbin Watershed and Conventional Control Measures

Invasive Species	Control[1]
Norway maple	Cut mature trees as close to base as possible. Pull seedlings/saplings including as much of the root as possible.
Japanese barberry	Pull young plants when ground is moist, and remove all root fragments. Repeated mowing can eliminate small populations. Mist apply 2% glyphosphate mixed with water and surfactant early in the season to cover plant, or apply 25% triclopyr directly to the outer 20% of cut stumps.
Japanese knotweed	Hand pull or grub plants, removing all fragments to prevent resprouting. Cut stems 2" above ground and immediately apply 25% solution of glyphosphate or triclopyr to cut stems. Follow with foliar spray of 2% glyphosphate or triclopyr with 0.5% non-ionic surfactant applied when outside temperatures are 65 degrees F or warmer, to control juvenile regeneration.
Oriental bittersweet	Regular mowing of edges and open areas will exclude bittersweet. Triclopyr herbicides are effective as foliar or basal applications.
Buckthorns	Seedlings are easily pulled. Larger stems can be pulled or cut, and may be killed by repeated fire. Freshly cut stumps should be treated with a 50% solution of glyphosphate to prevent resprouting. As buckthorns enter dormancy later than most species, treatments should be applied mid to late autumn to reduce risk to non-target species.
Honeysuckles	Hand-pulling is effective for isolated shrubs less than 3 years old. Most effective control of larger populations occurs through cutting and basal application of 20% glyphosphate. Seeds are not long-lived, so returning to remove seedlings by hand every two years or so should eliminate the population in time. Repeated burning is only effective for a short time, as the shrubs continue to resprout indefinitely following fire.
Olives	Repeated cutting of mature stems and sprouts and pulling of new seedlings may be effective. Best control is achieved by cutting followed by either burial or herbicide treatment of cut stump.
Multiflora rose	Regular mowing, where feasible, will remove this plant. Larger shrubs should be pulled or dug out. Where mowing is not practical, cutting followed by stump treatment with glyphosphate to prevent resprouting, is effective.

[1] Control measures are from current literature but are <u>NOT</u> DWSP policy at this time.

5.5.5.3.1 MA Invasive Plants Advisory Group: Strategic Recommendations for MA

In February of 2005, the Massachusetts Invasive Plants Advisory Group, an ad hoc committee of private and public organizations brought together in 1999 to address invasive plant issues in Massachusetts, produced its *Strategic Recommendations for Managing Invasive Plants in Massachusetts*. These recommendations were intended to provide guidance to landowners, public and private, seeking to

address the issue of invasive plants in an effective and efficient manner. The document includes the following nine principle recommendations:

1. Massachusetts should develop and implement a strategic management plan based on the recommendations of the MIPAG and integrated with the existing Massachusetts Aquatic Invasive Species Management Plan to address introduced invasive plant species.

2. A strategic management plan for managing invasive plants in Massachusetts should include a scientifically objective assessment process; a system for early detection and rapid response; criteria for setting research, management and education priorities; and develop broad public and private partnerships integrating efforts from the local to national scales.

3. Massachusetts should adopt the MIPAG criteria for invasive plant assessment and recognize the list of plant species determined by this process to be Invasive, Likely Invasive or Potentially Invasive within the Commonwealth. It should maintain an ongoing, transparent assessment process using the MIPAG criteria and with the participation of both public and private interest groups. This assessment should inform invasive species management strategies. Prevention strategies should predominantly focus on species assessed as Potentially Invasive and controlling the spread of Invasive species into priority conservation areas. Candidate species for eradication strategies should be selected from among those assessed as Likely Invasive.

4. Massachusetts should establish and support a centralized means within state government for inter-agency coordination on invasive species management, in partnership with public and private sector interests. This mechanism should facilitate the production of a strategic management plan for invasive plant species in the Commonwealth based on MIPAG's recommendations. It should help coordinate invasive species management efforts within the Commonwealth and integrate efforts with regional and national partners.

5. Massachusetts should establish and support an effective early detection and rapid response system for invasive species that is well integrated with regional and national efforts.

6. Massachusetts should assign to a responsible entity the task of assessing invasive species research needs and priorities for Massachusetts. It should integrate the work of public and private research partners, actively develop sources of funding for this research, and maintain a centralized database of this research in easily accessible form and linked to regional or national databases of this type. Funding sources for needed research should be developed and promoted.

7. A strategic management plan for invasive species in Massachusetts should set priorities for prevention, control, eradication and restoration efforts. Prevention should emphasize an early detection and rapid response system for new invasions and education about best management and prevention practices directed at the primary vectors for spreading invasive plant material. Except where eradication is feasible, control efforts should always manage toward a desired status or outcome for conservation resources compromised by invasive plant species, rather than the invasive species itself. Priority areas for management should be determined by identifying at all scales the natural and cultural resources at risk from invasive species and conducting baseline assessments of invasive species at those sites.

8. Massachusetts should adopt a policy of targeted outreach and education to raise awareness of the extent of the invasive plant problem and of the importance of each of our roles in preventing and controlling invasive species. Public education should focus on those vectors of spread most likely to introduce invasive plants into priority areas. The Commonwealth should endorse and adopt the voluntary protocols established under the Saint Louis Declaration for all government agencies, and promote their adoption by nursery professionals, landscape architects, the

gardening public, and botanic gardens and arboreta in Massachusetts. Specifically, the Commonwealth should prohibit state agencies from purchasing or intentionally introducing species determined to be Invasive, Likely Invasive, or Potentially Invasive through the scientifically objective assessment process of the MIPAG. Commercial industries should adopt a carefully constructed phase-out of these species in the trade while accommodating the economics of current inventories and existing contracts. Education and outreach described herein should be sufficiently funded and implemented assertively in order to steadily reduce the consumer demand for these species.

9. Public and private partnerships should be endorsed and strengthened as part of a strategic management plan for invasive plants in Massachusetts. The transparent, collaborative work of the MIPAG should be encouraged and supported as the means of assessing invasive species for the Commonwealth. Regional and national Partnerships and sources of funding for invasive plant management should be promoted and integrated into invasives management efforts in Massachusetts.

5.6 Protection of Cultural Resources

Forest management activities may be detrimental to archaeological resources without appropriate controls. Modern harvesting methods employ a wide range of heavy machinery, some of which, because of weight distribution and/or tire characteristics, can do irreparable damage to prehistoric or historic sites. Skidding logs can further disturb the soil. Operations may entail clearing areas for landings, turn-a-rounds, and access roads. Archaeological sites that lie closest to the surface can be obliterated by such activities. It is these same type of sites – those that are the youngest in time (i.e., the Early, Middle and Late Woodland) – that were most susceptible to destruction by the plow of the local farmer, and thus represent a relatively scarce piece of the archaeological record.

Accordingly, the DCR Archaeologist is one of several specialists who review proposed silvicultural operations during the annual internal review process. The Archaeologist specifically evaluates and assesses the impacts that harvesting could potentially have on archaeological resources that exist at any given site.

5.6.1 Silviculture and Cultural Resource Management: Prehistoric Sites

Management Objective: DWSP will minimize ground disturbance during a harvest in order to protect archaeological resources.

Recommended Practices for Highly Sensitive Areas:

- The harvest should occur during the winter with frozen soil conditions.
- Skidding should not be permitted.
- A small, tracked, excavator platform feller buncher, with its long reach and weight distributing tracks, is best suited for these sensitive areas.
- Wheeled feller bunchers, with limited reach and high ground pressures, should not be employed.

Recommended Practices for Moderately Sensitive Areas:

- One or more of the Highly Sensitive Area restrictions will be recommended.

In advance of any silviculture operation (also known as harvesting lots) on a site, Quabbin foresters submit a detailed Lot Proposal and 1:12,000-scale map for simultaneous in-house and public review.* The proposal describes the purpose for prescribed silvicultural treatment for an individual lot. It includes detailed site-specific information: overstory and understory vegetation, local forest composition and condition, topography and soils, wetlands and wildlife, etc., as well as Environmental Quality and Engineering considerations and harvesting limitations such as the type of machinery required to protect the soils and residual vegetation. All cultural resources known to the foresters are identified: foundations, cellar holes, walls, wells, dams, and prehistoric sites.

Lot Proposals and the associated maps provide the basis for Impact Assessment for the DCR Archaeologist. Site visits are sometimes required in order to assess microenvironment and features not reflected on the 1:25,000-scale USGS basemaps. The primary analytical tool is a predictive model of prehistoric site potential, based on Site Location Criteria.

Archaeologists have analyzed the environmental characteristics of thousands of sites throughout New England, and have identified a number of topographical variables that are consistently associated with

* The Lot Proposals for each fiscal year are available to the public at the Quabbin Visitor Center in Belchertown and at the Swift River Valley Historical Society in New Salem.

prehistoric sites. These Site Location Criteria are the basis of the predictive model used by the DCR Archaeologist to assess the likelihood of prehistoric significance at any given location.

The most important criteria for determining the archaeological sensitivity of a lot are: slope < 5 - 7 degrees; the presence of well-drained soils; and the prehistoric availability of fresh water within 1,000 feet. Other variables that may also be factors include: aspect, available lithic sources (stone for toolmaking), and elevation above sea level. When one or more of these variables are met, a site is considered to have been an attractive location for Native American habitation or subsistence activities. Such sites are classified as *highly sensitive* or *moderately sensitive* for prehistoric archaeological resources.

5.6.2 Silviculture and Cultural Resource Management: Historic Sites

Management Objective: DWSP will undertake vegetation management on historic sites which are particularly vulnerable and significant, as determined on a case-by-case basis. Careful removal of brush, saplings and trees is typically labor-intensive and must be repeated as resprouting and new growth occurs.

Recommended Practices:

- Remove most small to medium sized brush, saplings and trees from on and within historical features ,such as cellar holes and their foundation walls, channelized stream beds, mill dams, and historic buildings.
- Remove vegetation by cutting as close to the ground as feasible. Vegetation should not be pulled, or otherwise dislodged in a manner that would affect root systems.
- A small, tracked, excavator platform feller buncher may be appropriate for tree removal in some cases where the terrain is sufficiently level and stable. This machine has a long reach which limits the need to bring equipment too close to the structure; it picks the tree up, so there is no concern about the direction of the fall; and the tracks tend to distribute the weight, thereby limiting soil compaction.

Some cultural resources on the Quabbin watershed are protected at least in part by overall management and access strategies (see Landscape and Landscape Features, section 2.7.3 above). Others are more vulnerable and may require direct management efforts.

Vegetation, if left to grow unchecked in and around stone foundations, dams, raceways, etc., may compromise and ultimately destroy these archaeological features. The control of vegetation growth in and around archaeological sites and historic structures may therefore be a high priority at some sites.

Dana Common: Past and Present

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6 Research, Inventory, and Monitoring Needs

The Division has supported a wide variety of watershed research, by providing access to its properties, directed management activities, and/or limited direct funding. Some of this research has primarily benefited the researcher, but the vast majority has also informed DWSP managers and improved or supported watershed management practices. While the research budget at DWSP is not constant, the value of contiguous, undeveloped watershed properties generally behind secure gates or patrolled on a regular basis has attracted many researchers who have their own funding. In addition, watershed properties have provided fertile backdrops for a wide range of graduate student research.

Listed below is a variety of research, inventory, or monitoring needs in the general areas of forests and forestry, wildlife, and cultural resources. These are listed in part to direct the Division's own efforts in the coming decade, but also as a specific reference for potential researchers who are looking for a project that would address the needs of the Division.

6.1 Forest and Forestry Needs

Understanding the complex interactions between forests, forestry, and water supply requires regular review of current research in combination with inventory, monitoring, and site-specific research within the properties under the care and control of DWSP. The following list of research needs is a sampling of projects that could begin to address knowledge gaps to better inform the process of watershed forest management on the lands surrounding and protecting Quabbin Reservoir.

1. **Continuous Forest Inventory Data Merging and Analysis.** The Division has maintained a fixed-plot, Continuous Forest Inventory system since 1960. The trees and other features of these plots have been remeasured at least every 10 years since their establishment. Given the large leaps in computer technology and data management each decade, there is a significant need to bring all past records, which were initially stored on paper and then punch cards, into a current, comprehensive and readily accessible modern database. Some of this process requires laborious data entry and merging, but once this is accomplished, it will be possible to mine this dataset for a very wide variety of information, including uncommon empirical evidence of growth and mortality rates, a comparison of these to known patterns of disturbance or climate change, or comparisons of changes in forest structure and composition among disturbed and undisturbed sites.

2. **Continuation of Research Comparing Natural and Deliberate Disturbances.** The Division initiated, in partnership with academic researchers, a long-term paired watershed study comparing the effects of deliberate (timber harvesting) versus natural (insect defoliation) disturbances to the background conditions of unmanaged controls during the previous management period. This study has included the installation of low-cost V-notch weirs to study water quantity in conjunction with stations for monthly grab sampling to document nutrient and sediment backgrounds, as well as automated water quality sampling to capture differences during storm and snowmelt events. This research is labor intensive and requires a commitment of personnel from both partners that has been difficult to maintain. However, having gathered a multi-year background of data from these first-order tributaries, it would be valuable to build this research to its full potential during the coming decade in order to provide the agency with site-specific quantification of water supply effects of land management practices and natural disturbances.

3. **Watershed Forest Management Information System.** In order to more directly relate the cumulative effects of long-term watershed forest management to changes in associated water resources, the Department of Natural Resources Conservation at the University of Massachusetts has been developing a Watershed Forest Management Information System (WFMIS). As this

model reaches full development, it would be beneficial to test its effectiveness for guiding management of the Quabbin forest. The WFMIS currently includes three components.

a. **Watershed Management Priority Indices.** The Watershed Management Priority Indices (WMPI) delineates zones that relate forest management practices to soils, water resources, and aquatic ecosystems and incorporate readily available spatial information to identify areas and/or practices with the greatest potential to either maintain or restore stream water quality.

b. **Forest Road Evaluation System.** Forest roads provide critical access to forest management areas, but also represent the most likely source of sediment transport to associated water resources. The Forest Road Evaluation System (FRES) is designed to identify and describe the stability of overlaps between the road system and water bodies in order to direct maintenance efforts to the most pressing priorities and prevent unacceptable non-point source pollution of these resources. During the summer of 2007, a seasonal worker will be hired to begin to gather information on the current status of culverts, a basic component of the FRES.

c. **Harvest Scheduling Review System. T**he Harvest Scheduling Review System provides a systematic method to use commonly available GIS data to track the cumulative hydrologic effects of period harvesting across the watershed forest in order to remain below threshold increases in water yield and associated water quality changes.

6.2 Wildlife and Wildlife Management Needs

The following projects represent a few areas where technical data would assist in more effectively managing wildlife resources.

1. **Biological Surveys and Inventories.** In order to minimize or avoid negative impacts of land management activities on wildlife and critical habitats, all proposed activities are reviewed by the wildlife biologist. However, only two biologists are responsible for all 4 watersheds within the Division, and it would be impossible to physically inspect the hundreds of proposed acres. The Division must rely on records of known occurrences of critical habitat or species. Although new information is added as it becomes available, the database is far from complete. Biological surveys conducted by qualified persons can provide critical additional information that will aid Division efforts to protect these resources during land management activities. Information should also be incorporated into GIS datalayers.

2. **Vernal Pool Surveys.** The Division completed a contract that mapped potential vernal pools on the watershed using color infrared photos. Over 500 potential pools were identified. These pools need to be surveyed to determine their status and to try and locate other unmapped pools. This mapping will be incorporated into GIS to facilitate land management planning.

3. **Habitat Use and Population Dynamics of an Expanding Moose Population in the Southern Portion of Its Range**. Moose populations continue to expand at Quabbin and throughout the state. Watershed lands within Quabbin most likely serves as corridors and core habitat for the species within the state. Little research has focused on moose populations in the southern extent of their range. There is a current effort to collar moose with GPS collars that is being conducted by UMass and MassWildlife. The Division should strive to support this research and potentially initiate other research projects. Research should focus on the habitat use and population dynamics of moose and the potential impact of an increasing moose population on forest growth and regeneration.

4. **An Independent Assessment of Deer Density on Quabbin Reservation**. In order to gain a better understanding of deer population dynamics at Quabbin, an independent assessment of deer density is necessary. Decisions about deer management strategies are currently based on information gained from the annual deer harvest and on periodic regeneration and browse surveys. Obtaining information on deer density, herd composition and reproduction through surveys (distance sampling, spotlight), mark-recapture, or aerial surveys would provide a much more detailed summary of deer dynamics and aid in the management process.

5. **Regional Population Dynamics, Sources of Food, and Movement Patterns of Gulls in Central Massachusetts.** Gulls (ring-billed, herring, and black-backed) are a critical water quality concern on Quabbin Reservoir. Seasonal increases in gull numbers can have direct and substantial impacts on the quality of water leaving the reservoir. Little is known, however, about the movements of these gulls, both locally and regionally. In addition, it is often assumed that regional landfills might provide gulls with their food supplies, but the importance of other sources of food (agricultural areas, commercial properties) is unclear. Finally, understanding population characteristics of these species can be useful when determining management strategies. Research to tag/mark and follow a sample of all 3 species of gulls would provide a wealth of useful information.

6.3 Biological Diversity Maintenance Needs

1. **Invasive Species Inventory and Monitoring.** During FY2008, the Natural Resources Section of the Division will produce a Division-wide invasive plant management plan. One of the first chores associated with this planning effort will be to design inventory methods and conduct or supervise an initial inventory of current populations of invasive plants. Monitoring the status of these species as active management is implemented will provide feedback on the effectiveness of the control efforts and guide priorities for limited management resources.

2. **Rare Species Inventory and Monitoring.** The Division has worked for many years to find and monitor populations of rare animal and plant species. However, it is highly likely that many populations exist that have yet to be identified. Since the critical first step to protecting these species is knowing where they are, there is an ongoing need to continue to prospect in likely habitats for their presence, and to then incorporate their protection in planning for overlapping or adjacent management activities.

3. **Rare or Uncommon Habitat Inventory.** During the last management period, as described in Section 2.6.2.3, the Division contracted with the University of Massachusetts Department of Natural Resources Conservation to classify and begin to identify rare and uncommon habitats on the Quabbin watershed. This report was completed and gave examples of these habitats. To continue this effort would next require a more thorough identification of all examples of these rare habitats in order to protect their critical features during management activities. While this occurs to some extent as part of the internal review process for proposed timber harvesting or road maintenance activities, there remains a significant amount of work to complete this inventory and then to map the results.

6.4 Long Range Cultural Resource Inventory and Management Initiatives

A great deal of progress has been made in the past decade identifying cultural resources and improving databases and mapping to make certain these resources are apparent when management activities overlap their locations. Nonetheless, more remains to be accomplished in order to provide full protection for these resources.

1. **Historic Sites Inventory.** Improve the Quabbin inventory of historic sites by adding attributes such as site age, owner, activities, and buildings, to the database. These data will be used to prioritize vegetation management efforts and improve the review of silvicultural operations.

2. **Prehistoric Sites Inventory.** Add known prehistoric sites to the Quabbin GIS database. Current protection for these sites is provided through the application of site location criteria for their likely occurrence, but this model has not been extensively tested at Quabbin.

3. **Effects of Historical Cultivation on Prehistoric Sites.** Conduct archaeological sampling of red pine plantations, which were primarily planted on previously cultivated land, to determine the nature of sub-surface disturbance and survival factor for prehistoric sites.

4. **Educational Signage.** Develop educational signs and displays on Native American land use of the region.

5. **University Field Schools.** Encourage local universities to conduct archaeological field schools on watershed lands to further test and refine site location criteria.

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7 Public Involvement: Public Review and Comments

Public input is an integral part of the development, refinement, and final release of the Quabbin Reservoir Watershed System: Land Management Plan 2007-2017. The Division worked closely with the Quabbin Watershed Advisory Committee (QWAC) in all stages of plan development; QWAC unanimously voted to approve the plan. The general public has been given several opportunities to read through the plan and provide comments. An initial public meeting was held in May 2005 to provide information and to solicit input on the planning process. Copies of the draft plan were distributed to watershed libraries and the document was also available online for two months. A well-advertised public meeting was held July 12th, 2007 at the Quabbin Visitor's Center to present the draft plan. Public comments were submitted during the public hearing as well as in writing through the U.S. mail and a dedicated e-mail address.

The Division received many thoughtful and helpful comments from a variety of individuals and organizations. Every comment was read and carefully considered. These comments were very useful and improved the quality of the plan. Because so many comments were received, it would be tedious to specifically address each one in this summary. Certain themes or topics, however, appeared regularly in the comments. These topics are presented below in a form that incorporates the questions or comments of several different reviewers; the Division's responses follow in italics.

1. **There was concern from several reviewers about the growing moose population in Massachusetts and its impact on the current and future forests of Quabbin. Several reviewers thought existing moose populations were causing damage to the Quabbin forest and were likely to have significant impacts in the future. Some recommended developing a plan to deal with moose, including options to control populations.**

   Moose populations, both locally and statewide, have been a topic of internal discussion for several years. The Division recognizes the potential impacts a large, unregulated herbivore with essentially no natural predators can have on a forested landscape. As a result, the Division has taken many steps to gather information on local populations and to participate in moose related activities including:

   a. *Funding moose related research.*
   b. *Testifying to legislators about the potential impact of moose on water supply protection forests (moose in Massachusetts are currently protected and cannot be harvested).*
   c. *Conducting several different surveys to estimate moose populations (specifically section 5.4.4.5.3 in the land management plan).*

   In addition, the Division continues its ongoing efforts to monitor regeneration across the watershed. The most recent regeneration surveys indicate that regeneration is responding well. There is anecdotal evidence to suggest that localized browsing by moose can be heavy. While the Division is concerned about browsing (from deer and moose), browsing pressure is not yet great enough to stop DCR from conducting regeneration cuts. The Division also recognizes that if moose management is not addressed in the near future, the population could reach a point where it will reduce regeneration to an unacceptable level. If regeneration fell below this level, the Division would reevaluate its forest management approach.

   The Division will continue to monitor moose populations using a variety of survey techniques. In addition, our efforts to monitor regeneration will continue. Finally, the Division will strongly support any legislation that allows moose to be managed as a game species. If and when moose become an unprotected species that can be harvested, the Division will begin to evaluate how and when a moose management plan might be applied to Quabbin.

2. **A couple of reviewers expressed concerns about existing and potential threats to the forest, including Hemlock Wooly Adelgid. They questioned whether the Division's proposed forest management strategy was enough to respond to these threats.**

   In addition to the threat of the Hemlock Wooly Adelgid, this watershed forest is threatened by a wide variety of other exotic and native insect pests, invasive plant species, new and long-standing diseases, extreme weather events, and changes in climate, all of which are acknowledged in the plan. As described in the current and previous land management plans, it is the Division's belief that the best possible preparation for these threats is to develop and/or maintain forest diversity – in species composition, age classes, and structure. This is the primary objective of the forest management strategy described in the plan. While altering these landscape level threats is beyond the realm of possibilities for Quabbin's managers, pre-conditioning the forest to be more resistant to them and more resilient following their arrival is a fundamental obligation of watershed forest management and one taken very seriously by the Division.

3. **Several reviewers voiced their concerns about the Division's approach to forest management, including the allowance of larger patch cuts (up to 2 acres in Zone 3 with a small percentage of cuts > 2 acres). Further, questions were raised about maintaining tree species diversity, the aesthetics of larger patch cuts, and what some felt was a "cookie cutter" style of forest management.**

   The new Quabbin land management plan does provide foresters a wider range of silvicultural options by allowing larger (up to 2 acre) patch cuts than were allowed in the previous plan (which allowed openings up to 1 acre for most of the cutting). Although larger patch cuts are allowed, this plan emphasizes the importance of diversity. Therefore, a wide range of silvicultural treatments will be applied across the landscape, dictated by site and stand conditions, the zone in which the cutting takes place, and what landscape features are present.

   Tree species diversity is an important component of a watershed protection forest. To some extent, the forests at Quabbin in the future will be influenced by ecological changes (weather, disease, insects, etc.). The Division's goal has always been to develop and maintain a diversity of long-lived tree species that are well suited to each site. Furthermore, the Division has stated its intent to develop species diversity in the regeneration of the parts of the forest that were previously under heavy browsing pressure by deer, and that this diversity should mimic the diversity that exists in areas that have been continuously hunted. To accomplish this goal, the Division implements a wide range of silvicultural techniques across the forest, with a range of results from those that meet objectives to situations that require further silvicultural adjustments. Some areas that had regenerated during moderate to high deer levels are dominated by species that are not preferred browse, including white pine and black birch. In addition, the Division has committed to increase post-harvest monitoring of forestry lots. This monitoring will allow the Division to more thoroughly track regeneration progress over time and provide more complete information on species diversity.

   It is important to understand that the condition of all forests, either recently harvested or unmanaged, is constantly changing. While newly regenerated forests often have a "messy" or sparse look, this appearance changes rapidly. Within a few years, these patches are filled with regenerating trees, brambles, and forbs. In addition, the Division will often leave groups of trees in place in larger cuts, either because they contain exceptional trees that foresters want to save or to provide ecological benefits. These small reserves often add to the aesthetic appeal of a patch cut.

4. **How do you decide where you are going to cut and what type of silvicultural treatment to prescribe?**

Where the Division cuts is determined primarily by stand conditions. Priority is given to stands that lack species and/or structural diversity (e.g. plantations), are at risk of not surviving another 10 years (usually due to insect and disease problems), contain non-native species, or have a declining overstory and delayed regeneration. These stands lack structural and species diversity and do not provide the best watershed cover. Consideration is also given to stands that have advance regeneration or stands that are dominated by low vigor or poor quality trees and can be improved through silvicultural treatments.

The amount of acreage in the managed Quabbin forest that meets one or more of the above conditions is far greater than what the Division has set as a goal (to regenerate about 400 acres annually for the next decade). Therefore, the Division utilizes a system that prioritizes stands to be treated and insures that harvesting will be interspersed throughout the watershed. This system divides the watershed into units that are easily located on the ground. Ten percent of these units will be inventoried every year to help prioritize which stands need treatment the most. Some of the inventory information can be obtained from recent aerial photographs, but information is also obtained from the forester's knowledge of the area. Based on this inventory, 10% of that particular unit (1% of the managed forest area) will be regenerated. After 10 years the entire managed forest will have been inventoried, and if the management objectives remain the same, the process will start over.

Another restriction that could impact the harvest location is the 25% limitation within subwatersheds (Section 5.2.3.2). This restriction stipulates that not more than 25% of any subwatershed will be harvested within a 10 year period. While these guidelines will dictate where and when harvesting takes place during regular operations, a large natural disturbance could alter these management plans.

The silvicultural prescription is also based on stand conditions and the self imposed limits of the Quabbin zoning system. Older stands are generally better candidates for a regeneration type harvest, while younger stands are more suited for an intermediate type harvest. Intermediate cuttings are a combination of thinning and timber stand improvement work.

There are a number of silvicultural techniques to choose from in each zone ranging from single tree selection to full overstory removals greater than 10 acres, depending on which zone the proposed cutting overlaps (5.2.3.3.2). In the larger openings, reserve trees can be retained to provide residual structure and aesthetic appeal. In stands where advance regeneration is lacking but desired, shelterwood and seed tree techniques may be used to regenerate the openings.

Ultimately, the type of regeneration harvest that is applied will depend on overstory and understory type, amount of advance regeneration, soil type, desired species composition for regeneration, as well as concerns about water quality, wildlife, cultural resources, and aesthetics.

5. What types of logging equipment are used at Quabbin? How do you decide what type of equipment is allowed in each forestry lot, and are certain types of equipment excluded?

While many types of logging equipment can be used at Quabbin, some timber sales do have site-specific equipment restrictions to reduce negative impacts. For example, forestry lots that involve a corduroyed wetland crossing may be restricted to a forwarder transport system because the forwarder is less likely to disturb the wetland crossing. Similarly, lots that are limited to small landing sites or lots that can not accommodate straight skid roads are sometimes restricted to forwarders only. Some equipment restrictions are also imposed by the State Archeologist to protect cultural resources or are the result of guidelines in the Forest Cutting Practices Act for harvesting in filter strips. In areas with moist or mesic soils, restrictions may be imposed to exclude heavy equipment or equipment with small tires in order to prevent rutting in the soft soils.

While matching equipment to site conditions can help reduce negative impacts to the site, sometimes utilizing a skilled, conscientious equipment operator can have the most dramatic impact. For example, on sites with advance regeneration, using a cable skidder with a skilled operator who can directionally fell trees and pull the cable through the regeneration may often do less damage than a more mechanized operation. However if the operator cannot or will not directionally fell trees or pull cable through the regeneration, then the more mechanized operation may have less impact.

6. **Invasive plants were mentioned by different reviewers as being a potential problem throughout the Quabbin. Specifically, they were concerned about invasive plants in relation to disturbance from forest management, and wanted to know how the Division approached invasive species and their control.**

Invasive plants (and animals) are a nationwide problem and are pervasive throughout Quabbin and Massachusetts. It is important to recognize that invasive plants would be here with or without forest management. However, logging activities can accelerate the spread of invasive plants by altering site conditions that favor invasives, mechanically spreading invasive plants or seeds, or disturbing the area around existing populations of invasives and encouraging their spread. The Division is acutely aware of the potential impact of invasives on forest regeneration and management. In order to address these concerns, the Division will develop and formalize an invasive species management plan over the next year. This plan will clearly state what types of control methods will be utilized, prioritize how and where invasive populations will be tackled, and address the issue of forest management and its role in invasive species issues.

8 Literature Cited and General References

Aber, J.D. 1992. Nitrogen cycling and nitrogen saturation in temperate forest ecosystems. In: TREE. 7(7):220-224.

Aber, J.D. 1993. Modification of nitrogen cycling at the regional scale: the subtle effects of atmospheric deposition. pp. 163-174. In: McDonnell, M.J. and S.T.A. Pickett (eds.), Humans as components of ecosystems: the ecology of subtle human effects and populated areas. Springer-Verlag, N.Y. 364 pp.

Aber, J.D., D.B. Botkin, and J.M. Melillo. 1978. Predicting the effects of different harvesting regimes on forest floor dynamics in northern hardwoods. Can. J. For. Res. Vol 8: 306-315

Aber, J.D., J. Knute, P.S. Nadelhoffer, P. Steudler, and J.M. Melillo. 1989. Nitrogen saturation in northern forest ecosystems: excess nitrogen from fossil fuel combustion may stress the biosphere. Bioscience. 39(6):378-386.

Aber, J.D., J.M. Melillo, and C.A. McClaugherty. 1989. Predicting long-term patterns of mass loss, nitrogen dynamics, and soil organic matter formation from initial fine litter chemistry in temperate forest ecosystems. Canadian Journal of Botany. 68:2201-2208.

Aber, J.D., J.M. Melillo, K.J. Nadelhoffer, J. Pastor, and R.D. Boone. 1991. Factors controlling nitrogen cycling and nitrogen saturation in northern temperate forest ecosystems. Ecological Applications, l(3), pp. 303-315.

Agren, G.I. and E. Bosatta. 1988. Nitrogen saturation of terrestrial ecosystems. Environmental Pollution, 54: 185-197.

Aiken, G.R., Capel, P.D., Furlong, E.T., Hult, M.F., and Thorn, K.A., 1991. Mechanisms controlling the transport of organic chemicals in subsurface environments, in Mallard, G.E., and Aronson, D.A., eds., U.S. Geological Survey Toxic Substances Hydrology Program--Proceedings of the technical meeting, Monterey, California, March 11-15, 1991: U.S. Geological Survey Water-Resources Investigations Report 91-4034, p. 633-637

Alverson, W.S., and D.M.Waller. 1997. Deer populations and the widespread failure of hemlock regeneration in northern forests. *In*: The Science of Overabundance: deer ecology and population management. Smithsonian Institution Press. 402pp.

American Forest Council. 1986. Your water - a forest product. GreenAmerica, American Forest Council, 1250 Connecticut Ave., NW, Washington, D.C. 20036

Anacostia Restoration Team. 1992. Watershed restoration sourcebook. In: Collected papers presented at the conference: Restoring our home river: water quality and habitat in the Anacostia. Nov. 6 and 7. College Park, MD.

Angelstam, P., P. Wikberg, P. Danilov, W.E. Faber, and K. Nygren. 2000. Effects of moose density on timber quality and biodiversity restoration in Sweden, Finland, and Russian Karelia.Alces. 36: 133-145.

Apple, L.L. 1983. The use of beavers in riparian/aquatic habitat restoration in a cold desert, gully-cut stream system: a case history. Proceeding of the 18th Annual Meeting Amercian Fisheries Society, Laramie, Wyoming, pages 29-35.

Apple, L.L. no date. Riparian habitat restoration in cold desert, gully-cut stream systems: an innovative, cost effective, ecological approach. unpubl. manuscript. U.S. Bureau of Land Management, Rock Springs, Wyoming.

Arbogast, C., Jr. 1985. Marking guides for northern hardwoods under the selection system. USDA Forest Service, Lake States Forest Experiment Station Paper 56, 19 pp.

Armstrong, G.W. 1999. A stochastic characterization of a natural disturbance regime of the boreal mixed wood forest with implications for sustainable forest management. Can. J. For. Res 29(4): 424-433.

Arora, K. S.K. Michelson, J.L. Baker, D.P. Tierney, and C.J. Peters. 1996. Herbicide retention by vegetative buffer strips from runoff under natural rainfall. Transactions of the American Society of Agricultural Engineers 39(6):2155-2162.

Art, H.W. and D.P. Dethier. 1986. Influence of vegetative succession on soil chemistry of the Berkshires. Water Resources Research Center Publication, University of Massachusetts, Amherst, Project No. G912-05.

Attiwill, P.M. 1994a. The disturbance of forest ecosystems: the ecological basis for conservative management. Forest Ecology and Management, 63:247-300.

Attiwill, P.M. 1994b. Ecological disturbance and the conservative management of eucalypt forests in Australia. Forest Ecology and Management, 63:301-346.

Austin, P., R. Bishop, D. Chandler, P. Deslauriers, and M. Hopkinson. 1992. 1992 water quality report: Quabbin Reservoir and Ware River watersheds. Metropolitan District Commission, Division of Watershed Management. 120 pp.

Austin, P., R. Bishop, D. Chandler, and P. Deslauriers. 1990. 1990 water quality report: Quabbin Reservoir and Ware River watersheds. Metropolitan District Commission, Division of Watershed Management. 89 pp.

Baker, John H. 1984. Sulfate retention by Forest Soils of Central New England. Publication No. 151, Water Resources Research Center, University of Massachusetts at Amherst.

Banks, C.C. 1973. The strength of trees. Journal of the Institute for Wood Science, 6:44-50.

Barnes, D. M., and A. U. Malik. 2001. Effects of beaver (*Castor canadensis*) herbivory on streamside vegetation in a northern Ontario watershed. Canad. Field Nat. 115.

Barnes, William J., and Eric Dribble. 1988. The effects of beaver on riverbank forest succession. Can. J. Bot. 66:40-44.

Barten, P.K. 2006. "Water in the Woods", notes from a practical seminar delivered to professional foresters.

Batchelder, G.L., Yuretich, R.F. and W.C. Leonard. 1983. Hydrogeochemical cycling in a watershed-groundwater system: Fort River and Cadwell Creek, Massachusetts. Water Resources Research Center, University of Massachusetts. Pub. No. 145. 80 pp.

Benton, C., F. Khan, P. Monaghan, W.N. Richards and C.B. Shedden. 1983. The contamination of a major water supply by gulls (Larus sp.): a study of the problem and remedial action taken. Water Res. 17:789-798.

birds in southern New England. J. Wildl. Manage. 50(3):398-405.

Beschta, R.L. 1990. Effects of fire on water quantity and quality. In: Walstad, J.D., S.R. Radosevich, D.V. Sandberg, eds. Natural and prescribed fire in Pacific Northwest forests. Corvallis, OR. Oregon State University Press. 219-232.

Bishop, R.P. 1992. Quabbin Reservation sanitary district: a survey of potential water pollution sources. Metropolitan District Commission, Division of Watershed Management.

Blackburn, P. and J.A. Petty. 1988. Theoretical calculations of the influence of spacing on stand stability. Forestry, 61: 235-244

Blodget, B. G. and R.A. Clark. no date. A check list for birds of the Quabbin Reservation, west central Massachusetts. Friends of Quabbin, Belchertown.

Blodgett, D. 1985. Snag and den tree management guidelines. Habitat Highlights. Vol. 5. No. 4. 2pp.

Bolgiano, C. 1989. A case for eastern old-growth. Amer. Forests. May-June:26-31,48.

Bormann, F.H. and G.E. Likens. 1979a. Catastrophic disturbance and the steady state in Northern Hardwood Forests. American Scientist 67:660-669.

Bormann, F.H. and G.E. Likens. 1979b. Patterns and process in a forested ecosystem; disturbance, development and the steady state based on the Hubbard Brook Ecosystem Study. Springer-Verlag. New York, N.Y. 253 pp.

Bormann, F.H. and G.E. Likens. 1970. The nutrient cycles of an ecosystem: measurements taken in a New Hampshire forest. Scientific American. 223(4).

Bormann, F.H., G.E. Likens, and J.S. Eaton. 1969. Biotic regulation of particulate and solution losses from a forest ecosystem. Bioscience Vol 19, July, pp 600-610.

Bormann, F.H., G.E. Likens, D.W. Fisher, R.S. Pierce. 1968. Nutrient loss accelerated by clear-cutting of a forest. Ecosystem Science, February, pp 882-884.

Bormann, F.H., G.E. Likens, T.G. Siccama, R.S. Pierce, and J.S. Eaton. 1974. The export of nutrients and recovery of stable conditions following deforestation at Hubbard Brook. Ecol. Monographs 44:255-277.

Bowden, R.D., M.S. Castro, J.M. Melillo, P.A. Steudler and J.D. Aber. 1993. Fluxes of greenhouse gases between soils and the atmosphere in a temperate forest following a simulated hurricane blowdown. Biogeochemistry, 21:61-71.

Bradshaw, F.J. 1992. Quantifying edge effects and patch size for multiple-use silviculture – a discussion paper. Forest Ecology and Management. 48:249-264.

Brandner, T.A., R.O. Peterson, and K.L. Risenhoover. 1990. Balsam fir on Isle Royale: effects of moose herbivory and population density. Ecology. 71(1): 155-164.

Branvold, D.K., C.J. Popp and J.A. Brierly. 1976. Waterfowl refuge effect on water quality: II. chemical and physical parameters. Journal of Water Pollution Control Fed. 48(4):680-687.

Brayton, D. Scott. 1984. The beaver and the stream. Journal of Soil Water Conservation. March/April: 108-109.

Broadmeadow, M.S.J. (ed). 2001. Climate change and U.K. forests. Forestry Commission Bulletin #125. Forestry Commission, Edinburgh. 198 p.

Bromley, P. T., J. Starr, J. Sims, and D. Coffman. 1997. A landowner's guide to wildlife abundance through forestry. University of Virginia Cooperative Extension. Publication: 420-138.

Bromley, S.W. 1935. The original forest types of southern New England. Ecol. Monographs Vol 5(1), January, pp 63-89.

Brooks, K.N., P.F. Ffolliott, H.M. Gregersen, and L.F. DeBano. 1997. Hydrology and the management of watersheds. 2nd Edition. Iowa State University Press. Ames, IA

Brooks, R.T. and T.D. Kyker-Snowman. 2007. Forest floor temperature and relative humidity following timber harvesting in southern New England, USA. Forest Ecology and Management. Accepted July 21, 2007. *In press*.

Brown, G.W. 1976. Forestry and water quality. School of Forestry, Oregon State University, Corvallis, Oregon. Reprinted by the Oregon State University Book Stores, Inc.

Brown, K.A., P.H. Freer-Smith, G.D. Howells, R.A. Skeffington, and R.B. Wilson. 1988. Rapporteurs report on discussions at the workshop on excess nitrogen deposition, Leatherhead, September 1987. Environmental Pollution, 54:285-295.

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. Distance sampling: estimating abundance of biological populations. Chapman & Hall, London. 446 pp.

Burns, R.G. and J.D. Hewlett. 1983. A decision model to predict sediment yield from forest practices. Water Resources Bulletin Vol 19, No 1, pp 9-14.

Burns, R.M. and B.H. Honkala, tech. coords. 1990. Silvics of North America: Vol.1. Conifers, Vol.2. Hardwoods. Agricultural Handbook No.654. U.S. Department of Agriculture, Forest Service, Washington, D.C. Vol.1. 675 pp.; Vol.2. 877 pp.

Buzzell, G. 1991. 1990 Wachusett storm salvage study. MDC Publication.

Buzzell, G. 1993. Study of regeneration response at Walnut Hill, Sudbury Reservoir watershed. Unpublished MDC report.

Carlson, J. 1994. Effects of a simulated hurricane on downed woody fuel loading in a central Massachusetts hardwood stand. Abstr. 5th Ann. Harvard Forest Ecology Symp., April 25.

Carlton, M. 1990. Literature review: water quality implications of converting forested watersheds to principally herbaceous cover - implications to the Quabbin watershed. MDC Publication.

Carroll, C.F. 1973. The timber economy of puritan New England. Brown University Press, Providence, RI. Pp.221

Chadwick, N.L., D. R. Progulske, and J. T. Finn. 1986. Effects of fuelwood cutting on

Chang, M. 2003. Forest hydrology: an introduction to water and forests. CRC Press LLC, Boca Raton, FL. 373 p.

Chen, H. and T.J. Cutright. 2003. Preliminary evaluation of microbially mediated precipitation of cadmium, chromium, and nickel by rhizosphere consortium. Journal of Environmental Engineering – ASCE. 129(1):4-9.

Christ, M.J., W.T. Peterjohn, J.R. Cumming, and M.B. Adams. 2002. Nitrification potentials and landscape, soil and vegetation characteristics in two central Applachian watersheds differing in NO_3- export. For Eco Manage 159: 145-158.

Clark, D. E. 1999. Quabbin and Wachusett Reservoir Watersheds Aquatic Wildlife Pathogen Control Zones. Metropolitan District Commission, Division of Watershed Management, Natural Resources Section. 17pp.

Clark, D.E. 2004**.** Quabbin Reservation White-Tailed Deer Impact Management Program: 5-Year (2000-2004) Review and New 5-Year Plan (2005-2009). Dept. Cons. And Recreation. Div. of Water Supply Prot.

Cline, A.C. 1939. The restoration of watershed forests in the hurricane area. Journal of the New England Water Works Association. 53(2):223-237.

Cline, A.C. and S.H. Spurr. 1942. The virgin upland forest of central New England: a study of old growth stands in the Pisgah Mountain section of southwestern New Hampshire. Harvard Forest Bulletin No 21, 58 pp.

Connecticut Department of Environmental Protection. 1991. Guidelines for enhancing Connecticut's wildlife habitat through forestry operations. Dept. Environ. Prot. Wildl. Div. 14pp.

Connor, K.J., W.B. Ballard, T. Dilworth, S. Mahoney, and D.Anions. 2000. Changes in structure of a boreal forest community following intense herbivory by moose. Alces. 36: 111-132.

Cooper-Ellis, S., D.R. Foster, G. Carlton, and A. Lezberg. 1999. Forest response to catastrophic wind: results from an experimental hurricane. Ecology 80(8): 2683-2696.

Corbett, E.S. and W. Spencer. 1975. Effects of management practices on water quality and quantity: Baltimore, Maryland municipal watersheds. In: Municipal Watershed Management Symposium Proceedings, USDA Forest Service General Technical Report NE-13, pgs. 25-31.

Cosby, B.J., Wright, R.F., Hornberger, G.M., and J.N. Galloway. 1985. Modeling the effects of acid deposition: estimation of long-term water quality responses in a small forested catchment. Water Resources Research 21(11):1591-1601.

Crabtree, R.C. and F.A. Bazzaz. 1993. Seedling response of four birch species to simulated nitrogen deposition: ammonium vs. nitrate. Ecological Applications 3(2) pp. 315-321.

Craun, G.F. 1984. Waterborne outbreaks of giardiasis, current status. IN: Erlandsen and Meyer (eds.). Giardia and Giardiasis. Plenum Press. N.Y. pgs.. 243-261.

Cronin, W. 1983. Changes in the land: Indians, colonists, and the ecology of New England. Hill and Wang. New York, NY. 241 pp.

Curran, M.L. and D. F. Dincauze. 1977. Paleo-Indians and paleo-lakes: new data from the Connecticut drainage. Annals of the New York Academy of Sciences. 288:333-348.

Currie, W. and J.D. Aber. 1994. Modeling litter decomposition and N dynamics across LTER sites as part of the LIDET study. Abstracts from the 5th Annual Harvard Forest Ecology Symposium. Petersham, MA.

Currier, J.B., L.E. Siverts, and R.C. Maloney. 1979. An approach to water resources evaluation of non-point sources from silvicultural activities - a procedural handbook. In: Best Management Practices for Agriculture and Silviculture: Proceedings of the 1978 Cornell Agricultural Waste Management Conference, Ann Arbor Science Publishers Inc., Ann Arbor, Michigan

Curtis, J.T. 1959. The vegetation of Wisconsin. Univ. Wisconsin Press, Madison. 657 pp.

Danell, K., L.Edenius, and P.Lundberg. 1991. Herbivory and tree stand composition: moose patch use in winter. Ecology. 72(4): 1350-1357.

Davies, R.B. and C.P. Hibler. 1976. Animal reservoirs and cross-species transmission of Giardia. pp. 104-126 IN: Jakubowski and Hoff (eds). Waterborne transmission of giardiasis. U.S. EPA - 600/9-79-001.

Davis, M.B., 1969. Climatic changes in southern Connecticut recorded by pollen deposition at Rogers Lake. Ecology 50, 409–422.

Davis, M.B., 1983. Holocene vegetational history of the eastern United States.In: Wright Jr., H.E. (Ed.), Late Quaternary Environments of the United States: Volume 2, The Holocene. University of Minnesota Press, Minneapolis, Minnesota, pp. 166–181.

Davis, J.W., G.A. Goodwin, and R.A. Ockenfels. 1983. Snag habitat management: proceedings of the symposium. U.S. For. Serv. Gen. Tech. Rep.RM-99. 226pp.

Day, G.M. 1953. The Indian as an ecological factor. Ecology. 34(2): 329-347.

DeBano, L.F., D.G. Neary, and P. F. Ffolliott. 1998. Fire's effects on ecosystems. John Wiley Publishers, Inc., New York, NY. 333 p.

DeCoster, L.A. and J. Herrington. 1988. Is a tree a heavy drinker, or does it just pump water? The American Tree Farmer, May-June, 1988.

DeGraaf, R.M. and D.A. Richard. 1987. Forest wildlife of Massachusetts: cover type, size class and special habitat relationships. Univ. Mass. Coop. Ext. Serv. Publ. C-182.

DeGraaf, R.M., and A.L. Shigo. 1985. Managing cavity trees for wildlife in the Northeast. U.S. For. Serv. Gen. Tech. Rep. NE-101. 21pp.

DeGraaf, R.M., and D.D. Rudis. 1986. New England wildlife: habitat, natural history, and distribution. U.S. For. Serv. Gen. Tech. Rep. NE-108. 491pp.

DeGraaf, R.M., and K.E. Evans. 1980. Management of north central and northeastern forests for nongame birds. U.S. For. Serv. Gen. Tech. Rep. NC-51. 275pp.

DeGraaf, R.M., and W.M. Healy. 1988. Is forest fragmentation a management issue in the northeast? U.S. For. Serv. Gen. Tech. Rep. NE-140. 32pp.

DeGraaf, R.M., M. Yamasaki, W.B. Leak, and J.W. Lanier. 1992. New England wildlife: management of forested habitats. U.S. For. Serv. Gen.Tech. Rep. NE-144. 271pp.

De la Cretaz, A.L. and P.K. Barten. 2007. Land use effects on streamflow and water quality in the Northeastern United States. CRC Press. Boca Raton, FL. 319 pp.

DeMaynadier, P. G., and M. L. Hunter, Jr. 2000. Road effects on amphibian movements in a forested landscape. Nat. Areas. J. 20:56-65.

Dessecker, D.R., and D.G. McAuley. 2001. Importance of early successional habitat to ruffed grouse and American woodcock. Wildl. Soc. Bull. 29(2):456-465.

Dettmers, R. and K. Rosenburg. 2000. Partners in flight landbird conservation plan: physiographic area 9: southern New England. Version 1.0. American Bird Conservancy. Website: http://www.blm.gov/wildlife/plan/pl_09_10.pdf

Devito, K. J., and P. J. Dillion. 1993. Importance of runoff and winter anoxia to the P and N dynamics of a beaver pond. Can. J. Fish. Aquat. Sci. 50:2222-2244.

Diesch, S.L. 1970. Disease transmission of water-borne organisms of animal origin. pp. 269-285 IN: T.L. Willrich and G.E. Smith (eds). Agricultural practices and water quality. Iowa St. Univ. Press.

Dincauze, D.F. 1974. An introduction to archaeology in the greater Boston area. Archaeology of Eastern North America. 2(1):47.

Dincauze, D.F. and M.T. Mulholland. 1977. Early and middle archaic site distributions and habitats in southern New England. Annals of the New York Academy of Sciences. 288:439-455.

Dincauze, D.F.; P.A. Thomas; J.S. Wilson; and M.T. Mulholland. 1976. Cultural resource survey and impact evaluation report, state Route 2: Greenfield, Gill, Erving, Wendell, Orange, Franklin County, Massachusetts. University of Massachusetts, Amherst.

Dissmeyer, G.E., ed. 2000. Drinking water from forests and grasslands: a synthesis of the scientific literature. Gen. Tech. Rep. SRS-39. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 246 p.

Dobson, J.E., R.M. Rush, and R.W. Peplies. 1990. Forest blowdown and lake acidification. Annals of the Association of American Geographers. 80(3):343-361.

Donkor, N.T., and J.M. Fryxell. 1999. Impact of beaver foraging on structure of lowland boreal forests of Algonquin Provincial Park, Ontario. For. Ecol. Manage. 118:83-92.

Douglass, J.E. 1983. The potential for water yield augmentation from forest management in the eastern United States. Water Resources Bulletin Vol 19(3), pp 351-358.

Douglas, J.E. and W.T. Swank. 1975. Effects of management practices on water quality and quantity: Coweeta Hydrologic Laboratory, North Carolina. In: Municipal Watershed Management Symposium Proceedings, USDA Forest Service, General Technical Report, NE-13, pp 1-12

Douglass, J.E. and W.T. Swank. 1972. Streamflow modification through management of eastern forests. U.S.D.A. Forest Service, Research Paper SE-94, 15p.

Driscoll, Charles T., G.E. Likens, L.O. Hedin, J. S. Eaton and F.H. Bormann. 1989. Changes in the chemistry of surface waters: Twenty-five year results at the Hubbard Brook Experimental Forest, NH. Environ. Sci. Technol. 23(2):137-143.

Dunne, T. and L.B. Leopold. 1978. Water in environmental planning, W.H. Freeman and Company, New York, NY, 818 pp.

Dyrness, C.T. 1965. Erodibility and erosion potential of forest watersheds. In: Forest Hydrology: Proceedings of a National Science Foundation Advanced Science Seminar at Pennsylvania State University, University Park, PA, August 29-Sept 10, 1965, Edited by W.E. Sopper and H.W. Lull, Pergamon Press, London, pp 559-611.

Edenius, L. 1994. Foraging behavior by moose in forest stands subjected to severe browsing. Alces. 30: 37-40.

Edwards, Nicole T., and David L. Otis. 1999. Avian communities and habitat relationships in South Carolina Piedmont beaver ponds. Am. Midl. Nat. 141:158-171.

Elliot, C. A. 1988. A forester's guide to managing wildlife habitats in Maine. U. Maine Coop. Ext. 46pp.

Erlandsen, S.L. and W. J. Bemrick. 1988. Waterborne giardiasis: sources of Giardia cysts and evidence pertaining to their implication in human infection. pp. 227-236 IN: P.M. Wallis and B.R. Hammond (eds). Advances in Giardia research. Univ. Calgary Press, Calgary, Alberta.

Eschner, A.R. 1978. Long term observations and analyses of the hydrology of small, relatively natural watersheds in the Adirondack Mountains. Reprinted from: Tagungsbericht Forschung in mitteleuropaischen Nationalparken. Schriftenreihe des Bayerischen Staatsministeriums fur Ernahrung, Landwirtschaft und Forsten. Grafenau 25-27 Mai 1978.

Eschner, A.R. and D.L. Mader. 1975. Management implications of other hydrologic research in the northeast. In: Municipal Watershed Management Symposium Proceedings. USDA Forest Service: General Technical Report NE-13.

Eschner, A.R. and D.R. Satterlund. 1965. Forest protection and streamflow from an Adirondack watershed. Wat. Res. Res. 2(4):765-783.

Executive Office of Environmental Affairs, Commonwealth of Massachusetts. 2000. The state of our environment. 150 pp.

February 5-7, 2002. Rutgers – the State University of New Jersey, East Brunswick, NJ. 403 p.

Federal Register. 1987. 52(212):42178. Nov. 3.

Federer, C.A. and D. Lash. 1978. Brook: a hydrologic simulation model for eastern forests. Water Resource Research Center, University of New Hampshire, Durham, Research Report Number 19.

Fennell, H., D.B. James and J. Morris. 1974. Pollution of a storage reservoir by roosting gulls. Water Treat. Exam. 23:5-24.

Finzi, A.C., C.D. Canham, and N. Van Breemen. 1998. Canopy tree-soil interactions within temperate forests: species effects on ph and cations. Ecological Applications, 8(2), pp. 447-454

Flatebo, G., C. R. Foss, and S. K. Pelletier. 1999. Biodiversity in the forests of Maine: guidelines for land management. Univ. Maine Coop. Ext. No.7147 167pp.

Forman, R.T.T. and M. Godron. 1986. Landscape ecology. Wiley & Sons, N.Y.

Foster, D. R. 1999. Thoreau's country. Harvard University Press, Cambridge, MA.

Foster, D.R. 1988a. Species and stand response to catastrophic wind in central New England, U.S.A. Journal of Ecology 76:135-151.

Foster, D.R. 1988b. Disturbance history, community organization and vegetation dynamics of the old-growth Pisgah Forest, South-Western New Hampshire, U.S.A. Journal of Ecology 76:105-134.

Foster, D.R. and E.R. Boose. 1992. Patterns of forest damage resulting from catastrophic wind in central New England, U.S.A. Journal of Ecology 80:79-98.

Foster, D.R., J.D. Aber, J.M. Melillo, R.D. Bowden, and F.A. Bazzaz. 1997. Forest response to disturbance and anthropogenic stress. BioScience, 47:7, p 437.

Foster, N.W., Nicolson, J.A., and P.W. Hazlett. 1989. Temporal variation in nitrate and nutrient cations in drainage waters from a deciduous forest. Journal of Environmental Quality 18: 238-244.

France, R. L. 1997. The importance of beaver lodges in structuring littoral communities in boreal headwater lakes. Can. J. Zool. 75:1009-1013.

Franklin, J.F.; Spies, T.A.; Pelt, R.V.; Carey, A.B.; Thornburgh, D.A.; Berg, D.R.; Lindenmayer, D.B.; Harmon, M.E.; Keeton, W.S.; Shaw, D.C.; Bible, K.; Chen, J. 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. Forest Ecology and Management. 155: 399-423..

Franzmann, A.W., and C.C. Schwartz. 1997. Ecology and management of the North American moose. Smithsonian Institution Press and Wildlife Management Institute. 733 pp.

Freeman, S. 1987. Acid rain trimming health of forests. The Springfield Union. 22 May 1987: 17.

Frelich, L.E. 2002.Forest dynamics and disturbance regimes: studies from temperate evergreen-deciduous forests. Cambridge Studies in Ecology. University Press, Cambridge, U.K. 266 pp.

French, J.M. 1988. MDC-DFWELE land acquisition program: MDC watersheds. Unpublished MDC report.

French, J.M. and G.S. Buzzell. 1992. Wachusett Reservoir Arborvitae Hedge Report. MDC.

Garrett, J.D., T. Cassidy, K. McGarigal, K.B. Searcy, and R. Harrington. 2000. Rare, unique, and exemplary natural communities of Quabbin watershed. University of Massachusetts, Department of Natural Resources Conservation report prepared for MDC/DWM.

Garvey, E. 2000. Natural organic matter fate and transport in the Quabbin Reservoir. PhD Dissertation (unpublished). University of Massachusetts, Amherst, MA. Department of Civil and Environmental Engineering.

Geldreich, E.E. 1972. Water-borne pathogens. Chapter 9 In: Mitchell (ed.). Water pollution microbiology. John Wiley & Sons.

Gold, A. 1994. Riparian zone hydrology: ramifications for ground water pollution removal. Proc. Riparian Buffer Zones Conference. Nov. 21 and 22, Sturbridge, MA. P. Veneman, ed.

Goldstein, R.A., Chen, C.W., and S.A. Gherini. 1985. Integrated lake-watershed acidification study: summary. Water, Air, and Soil Pollution 26:327-337.

Goodale, C.L., J.D. Aber, and W.H. McDowell. 2000. The long-term effects of disturbance on organic and inorganic nitrogen export in the White Mountains, New Hampshire. Ecosystems 3:433-450.

Gould, D.J. and M.R. Fletcher. 1978. Gull droppings and their effects on water quality. Water Res. 12:665-672.

Gresham, C.A. 1996. Changes in bald cypress-swamp tupelo wetland soil chemistry caused by Hurricane Hugo induced saltwater inundation. In: Haymond, J.L. and W.R. Harms, eds. 1996. Hurricane Hugo: South Carolina forest land research and management related to the storm. Gen. Tech. Rep. SRS-5. Asheville, N.C.: U.S. Department of Agriculture, Forest Service, Southern Research Station. Pp. 266-270.

Hägglund, Å., and G. Sjöberg. 1999. Effects of beaver dams on the fish fauna of forest streams. For. Ecol. Manage. 115:259-266.

Hakanson, L., T. Andersson, and A. Nilsson. 1990. New method of quantitatively describing drainage areas. Environ. Geol. Sci 15(1):61-69.

Hall, C.A.S. and J.W. Day, Jr. 1977. Ecosystem modeling in theory and practice. Wiley-Interscience, New York, N.Y. 684p.

Hammerson, G.A. 1994. Beaver (Castor canadensis): Ecosystem alterations, management, and monitoring. Nat. Areas J. 14(1):44-57.

Harr, R.D. and R.L. Fredriksen. 1988. Water quality after logging small watersheds within the Bull Run watershed, Oregon. Water Resources Bulletin 24(5): 1103-1111.

Hartley, B.A. 1975. Current management practices on the Baltimore municipal watersheds. USDA Forest Service, General Technical Report NE-13

Hartman, E.M., P.E. Austin, and K.M. Keohane. 1992. Quabbin tributaries: water quality data report. Commonwealth of Massachusetts, Department of Environmental Protection and Metropolitan District Commission. Pub. No. 17158-195-50. 196 pp.

Haymond, J.L. and W.R. Harms, eds. 1996. Hurricane Hugo: South Carolina forest land research and management related to the storm. General Technical Report SRS-5. Asheville, N.C.: U.S. Department of Agriculture, Forest Service, Southern Research Station. 540 pgs.

Healy, W.M. 1997a. Influence of deer on the structure and composition of oak forests in central Massachusetts. *In*: The Science of Overabundance: deer ecology and population management. Smithsonian Institution Press. 402pp.

Healy, W.M. 1997b. Thinning New England oak stands to enhance acorn production. N. Journ. Appl. For. 14(3):152-156.

Healy, W.M., R.T. Brooks and P.J. Lyons. 1987. Deer and forests on Boston's municipal watershed after 50 years as a wildlife sanctuary. IN: Proceedings: deer, forestry, and agriculture: interactions and strategies for management. June 15-17, 1987. Warren, PA. Allegheny Society of American Foresters.

Healy, W.M., R.T. Brooks and R.M. DeGraaf. 1989. Cavity trees in sawtimber-size oak stands in central Massachusetts. North. J. Appl. For. 6(2):61-65.

Hedin, L.O., J.J. Armesto and A.H. Johnson. 1995. Patterns of nutrient loss from unpolluted, old-growth temperate forests: evaluation of biogeochemical theory. Ecology 76(2), 493-509.

Hemond, H., K. Eshleman, K. O'Connor, B. Gordesky, and D. Chen. 1987. Surface hydrology and wetland roles in acid deposition on the Bickford Pond watershed. Commonwealth of Massachusetts, Dept. of Environmental Quality Engineering, Project 84-26-WPC. 71 pp.

Hemond, H.F. and K.N. Eshleman. 1984. Neutralization of acid deposition by nitrate retention at Bickford watershed, Massachusetts. Water Resources Research. 20(11):1718-1724.

Herkert, J.R., R. E. Szafoni, V. M. Kleen, and J.E. Schwegman. 1993. Habitat establishment, enhancement and management for forest and grassland birds in Illinois. Ill. Dept. Conserv. Div. Nat. Herit. 1. 19pp.

Hewlett, J.D. 1978. Forest water quality: an experiment in harvesting and regenerating of Piedmont forest. University of Georgia, Athens, GA.

Hewlett, J.D. 1982. Principals of forest hydrology. University of Georgia Press. Athens, GA. 183 pp.

Hewlett, J.D. and W.L. Nutter. 1969. An outline of forest hydrology. University of Georgia Press, Athens, GA, 137 pp.

Hibbert, A.R. 1967. Forest treatment effects on waters yield. In: International Symposium on Forest Hydrology, W.E. Sopper and H.W. Lull, eds, Pergamon Press, Oxford, England, pp 527-543.

Hill, E.P. 1982. Beaver. pp. 256-281 IN: J.A. Chapman and G.A. Feldhammer (eds), Wild mammals of North America: biology, management and economics. John Hopkins Univ. Press.

Hobbie, J.E. and G.E. Likens. 1973. Output of phosphorus, dissolved organic carbon, and fine particulate carbon from Hubbard Brook watersheds. Limnology and Oceanography, 18(5):734-742.

Hobson, S.S., J.S. Barclay, and S.H. Broderick. 1993. Enhancing wildlife habitats: a practical guide for forest landowners. NE Reg. Agric. Engin. Serv. 172pp.

Hodkinson, I.D. 1975. Energy flow and organic matter decomposition in an abandoned beaver pond ecosystem. Oecologia (Berl.) 21:131-139.

Hoekstra, T.W., and J. Capp. 1988. Integrating forest management for wildlife and fish. U.S.D.A. For. Serv. Gen. Tech. Rep. NC-122. 63pp.

Hooper, M.C., K. Aril, and M.J. Lechowicz. 2001. Impact of a major ice storm on an old-growth hardwood forest. Can. J. Bot. 79(1): 70-75.

Hornbeck, J.W. and C.A. Federer. 1975. Effects of management practices on water quality and quantity: Hubbard Brook Experimental Forest, New Hampshire. In: Municipal Watershed Management: Symposium Proceedings. USDA Forest Service General Technical Report NE-13: 58-65.

Hornbeck, J.W. and J.N. Kochenderfer. 2004. A century of lessons about water resources in Northeastern forests., Chapter 2 In A century of forest and wildland watershed lessons, G.G. Ice and J. D. Stednick, eds., Society of American Foresters, 287 p.

Hornbeck, J.W., and W.B. Leak. 1992. Ecology and management of northern hardwood forests in New England. U.S.D.A. For. Serv. Gen. Tech. Rep. NE-159. 44p.

Hornbeck, J.W., C.W. Martin, and C.T. Smith. 1986. Protecting forest streams during whole-tree harvesting. Northern Journal of Applied Forestry Vol 3, Sept, pp 97-100.

Hornbeck, J.W., C.W. Martin, R.S. Pierce, F.H.Bormann, G.E. Likens and J.S. Eaton. 1987. Northern hardwood forest ecosystem: ten years of recovery from clearcutting. U.S.D.A. Forest Service, Northeastern Forest Experiment Station. Broomall, PA. NE-RP-596. 30 p.

Hornbeck, J.W., E.S. Verry, and C.A. Dolloff. 1994. Managing riparian areas in the northeastern forests: a quest for desired future conditions. Proceedings: Managing forests to meet peoples' needs. Society of American Foresters/Canadian Institute of Forestry Convention, September 18-22, Anchorage, Alaska, 299-304.

Hornbeck, J.W., G.E. Likens, R.S. Pierce, and F.H. Bormann. 1975. Strip cutting as a means of protecting site and streamflow quality when clearcutting northern hardwoods. *In* "Forest Soils and Land Management" (B. Bernier and C.F. Winget, eds.), pp.209-225. Presses Univ. Laval, Quebec.

Hornbeck, J.W., M.B. Adams, E.S. Corbett, E.S.Verry, and J.A. Lynch. 1993. Long-term impacts of forest treatments on water yield: a summary for northeastern USA. Journal of Hydrology, 150:323-344.

Hornbeck, J.W., R.S. Pierce, G.E. Likens, and C.W. Martin. 1975. Moderating the impact of contemporary forest cutting on hydrologic and nutrient cycles. In: The Hydrological Characteristics of River Basins Symposium, IAHS-AISH Publication No. 117, pp 423-433.

Horsley, S.B. and D.A. Marquis. 1982. Interference by weeds and deer with Allegheny hardwood reproduction. Can. J. For. Res. 13:61-69.

Houghton, J.L., ed. 1996. Climate change 1995: the science of climate change. Inter-Governmental Panel on Climate Change. Cambridge: Cambridge University Press. 584 p.

Hunt, F.M. 1961. Forest resources on Metropolitan District Commission lands surrounding Quabbin Reservoir. Master's Thesis. University of Massachusetts, Department Forestry and Wildlife Management, Amherst, MA. 128 pp.

Hunt, F.M. and D.L. Mader. 1970. Low density management - a means to increase timber yields while using less soil moisture. Mass. Agric. Exp. Sta. Bulletin No. 588, November.

Hunt, P.,and D. De Luca. 1997. Survey and management recommendations for grassland and shrubland birds in New Hampshire. Audubon Soc.of NH. 46pp.

Hunter, M.L. 1990. Wildlife, forests, and forestry; principles of managing forests for biological diversity. Prentice Hall, Englewood Cliffs, N.J. 370 pp.

Hunter, M.L. Jr. 1999. Maintaining biodiversity in forest ecosystems. Cambridge University Press. 698pp.

Hunter, W.C., D.A. Beuhler, R.A. Canterbury, J.L. Confer, and P.B. Hamel. 2001. Conservation of disturbance-dependent birds in eastern North America. Wildl. Soc. Bull. 29(2):440-455.

Hussong, D., J.M. Damare, R.J. Limpert, W.J.L. Sladenk, R.M. Weiner and R.R. Colwell. 1979. Microbial impact of Canada geese (Branta canadensis) and whistling swans (Cygnus columbianus columbianus) on aquatic ecosystems. Appl. Envir. Microbiol. 37:14-20.

Ice, G.G. and J.D. Stednick (eds). 2004. A century of forest and wildland watershed lessons. Society of American Foresters, Bethesda, MD. 287 pp.

Indiana Department of Natural Resources. Undated. Managing woodlands for wildlife. DNR. Manage. Series No. 3. 9pp.

Iverson, L.R., A.M. Prasad, B.J. Hale, and E.K. Sutherland. 1999. An atlas of current and potential future distributions of common trees of the Eastern United States. Gen. Tech. Rep. NE-265. Radnor, PA. U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 245 p.

Jensen, P. G., P. D. Curtis, and D. L. Hamelin. 1999. Managing nuisance beavers along roadsides: a guide for highway departments. Cornell University. 14pp.

Johnson, D.W. and R.I. VanHook, eds. 1989. Analysis of biogeochemical cycling processes in Walker Branch watershed. Springer-Verlag, New York, NY. 401 pp.

Johnson, E. and M. Stachiw. 1985. Topographic overview. In: Historic and archaeological resources of central Massachusetts, pp 7-20. Massachusetts Historical Commission, Boston.

Johnson, E.S. and T.F. Mahlstedt. 1984. Prehistoric collections in Massachusetts: The Johnson Craig collection, New Braintree, Massachusetts. Massachusetts Historical Commission, Boston.

Johnston, C.A. and R. J. Naiman. 1990. Aquatic patch creation in relation to beaver population trend. Ecology. 71(4):1617-1621.

Johnston, C.A. and R.J. Naiman. 1990. Browse selection by beaver: effects on riparian forest composition. Can. J. For. 20:1036-1043.

Johnston, W.S., G.K. Maclachlan and G.F. Hopkins. 1979. The possible involvement of seagulls (Larus sp.) in the transmission of salmonella in dairy cattle. Veterinary Record. 105:526-527.

Jones, A.L., and P.D. Vickery. 1998. Conserving grassland birds: managing agricultural lands including hayfields, crop fields, and pastures for grassland birds. Mass. Audubon Society. 17pp.

Jones, C., C. MacConnell, K. Coleman, P. Cox, P. Falloon, D. Jenkinson, and D. Powlson. 2005. Global climate change and soil carbon stocks; predictions from two contrasting models for the turnover of organic carbon in soil. Global Change Biology. 11: 154-166.

Jones, C.G., J.H. Lawton, and M. Shachak. 1997. Positive and negative effects of organisms as physical ecosystem engineers. Ecology. 78(7):1946-1957.

Jones, F., P. Smith and D.C. Watson. 1978. Pollution of a water supply catchment by breeding gulls and the potential environmental health implications. J. Inst. Wat. Eng. & Sci. 32:469-482.

Jones, W.R. 1951. The deer herd of Prescott Peninsula, Quabbin Reservation, and its ecology. M.S. Thesis, University of Massachusetts, Amherst. 126 pp.

Jordan, C.F. 1982. Amazon rain forests. American Scientist 70:394-401.

Kelty, M.J., D.B. Kittredge, Jr., T. Kyker-Snowman, and A.D. Leighton. 2003. The conversion of even-aged stands to uneven-aged structure in Southern New England. Northern Journal of Applied Forestry 20(3), pp 109-116.

Kimple, A. and W. Schuster. 2002. Spatial patterns of HWA damage and impacts on tree physiology and water use in the Black Rock Forest, southern New York. In: Proceedings: hemlock woolly adelgid in the eastern United States. February 5-7, 2002. B. Onken (ed). Rutgers – the State University of New Jersey, East Brunswick, NJ. 403 p.

King, D.A. 1986. Tree form, height growth, and susceptibility to wind damage in *Acer saccharum.* Ecology, 67: 980-990.

King, S.L., B.D. Keeland, and J.L. Moore. 1998. Beaver lodge distributions and damage assessments in a forested wetland ecosystem in the southern United States. For. Ecol. Manage. 108:1-7.

Kizlinski, M.L., D.A. Orwig, R.C. Cobb, and D.R. Foster. 2002. Direct and indirect ecosystem consequences of an invasive pest on forests dominated by eastern hemlock. Journal of Biogeography, 29:1489-1503.

Klein, R.M. and T.D. Perkins. 1988. Primary and secondary causes and consequences of contemporary forest decline. The Botanical Review. 54(1), Jan-Mar, 43 pp.

Klotz, R. L. 1998. Influence of beaver ponds on the phosphorus concentration of streamwater. Can. J. Fish. Aquat. Sci. 55:1228-1235.

Kochenderfer, J.N. and G.M. Aubertin. 1975. Effects of management practices on water quality and quantity: Fernow Experimental Forest, West Virginia. In: Municipal Watershed Management Symposium Proceedings, USDA Forest Service, General Technical Report, NE-13, pp 14-24.

Kochenderfer, J.N. and J.D. Helvey. 1974. Gravel greatly reduces soil losses from minimum-standard forest roads. USDA Forest Service, Parsons, West Virginia.

Kochenderfer, J.N., P.J. Edwards, and F. Wood. 1997. Hydrological impacts of logging an Appalachian watershed using West Virginia's best management practices. Northern Journal of Applied Forestry 14(4): 207-218.

Krug, E.C. and C.R. Frink. 1983. Acid rain on acid soil: a new perspective. Science. 221:520-525.

Kyker-Snowman, T.D. 1989a. Quabbin forest regeneration study. MDC Publication.

Kyker-Snowman, T. 1989b. Logging systems evaluation on the Wachusett Reservoir, November, 1989: summary of evaluation and analysis. MDC Publication

LaDeau, S.L. and J.E. Clark. 2001. Rising CO_2 levels and the fecundity of forest trees. Science. 292:95-98.

Larsen, D.R. and P.S. Johnson. 1998. Linking the ecology of natural oak regeneration to silviculture. Forest Ecology and Management , Vol. 106, no. 1, pp. 1-7.

Larson, F.R., P.F. Ffolliott, W.O. Rasmussen, and D.R. Carder. 1979. Estimating impacts of silvicultural management practices on forest ecosystems. In: Best Management Practices for Agriculture and

Silviculture: Proceedings of the 1978 Cornell Agricultural Waste Management Conference, Ann Arbor Science Publishers Inc., Ann Arbor, Michigan.

Lawrence, G.B., D.A. Burns and P.S. Murdoch. 1993. Work plan of the Neversink watershed study. United States Geological Survey. Albany, N.Y.

Leak, W.B. and C.W. Martin. 1975. Relationship of stand age to streamwater nitrate in New Hampshire. USDA Forest Service Research Note NE-211, 5 pp.

Leak, W.B. and J.H. Gottsacker. 1985. New approaches to uneven-age management in New England. Northern Journal of Applied Forestry. 2:28-31.

Leonard, W.C., R.F. Yuretich, and S.J. Pohanka. 1984. Hydrogeology and processes of acid neutralization in Cadwell Creek, Quabbin Reservation, Massachusetts. Water Resources Research Center, University of Massachusetts, Pub. No. 148. 122 pp.

Levno, A. and J. Rothacher. 1969. Increases in maximum stream temperatures after slash burning in a small experimental watershed. Res. Note PNW-110. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 7p.

Lewis, G.P. and G.E. Likens. 2000. Low stream nitrate concentrations associated with oak forests on the Allegheny High Plateau of Pennsylvania. Water Resources Res 36:3091-3094.

Li, R.M., K.G. Eggert, and D.B. Simons. 1979. Simulation of stormwater runoff and sediment yield for assessing the impact of silvicultural practices. In: Best Management Practices for Agriculture and Silviculture: Proceedings of the 1978 Cornell Agricultural Waste Management Conference, Ann Arbor Science, Ann Arbor, Michigan.

Litvaitis, J.A. 2001. Importance of early successional habitats to mammals in eastern forests. Wild. Soc. Bull. 29(2):466-473.

Lorimer, C. 1977. The presettlement forest and natural disturbance cycle of northeastern Maine. Ecology. 58(1):139-148.

Lovett, G.M., K.C. Weathers, and M.A. Arthur. 2002. Control of nitrogen loss from forested watersheds by soil carbon:nitrogen ratio and tree species composition. Ecosystems 5: 712-718.

Lovett, G.M., K.C. Weathers, and W.V. Sobczak. 2000. Nitrogen saturation and retention in forested watersheds of the Catskill Mountains, New York. Ecological Applications 10(1):73-84.

Lovett, G.M. and H. Rueth. 1999. Soil nitrogen transformations in beech and maple stands along a nitrogen deposition gradient. Ecol Appl 9:1330-1344.

Lowrance, R. 1994. Technical overview of water quality functions of riparian forest buffer systems. Proc. Riparian Buffer Zones Conference. Nov. 21 and 22, Sturbridge, MA. P. Veneman ed.

Lowrance, R. and G. Vellidis. 1994. A conceptual model for assessing ecological risk to water quality function of bottomland hardwood forests. Environmental Management 19(2):239-258.

Lull, H.W. and K.G. Reinhart. 1967. Increasing water yield in the northeast by management of forested watersheds. USDA Forest Service Research Paper NE-66.

Lull, H.W. and K.G. Reinhart. 1972. Forests and floods in the eastern United States. In: Readings in forest hydrology, Eschner, A.R. and P.E. Black, Eds, MSS Information Corp., New York, N.Y.

Lynch, J.A., W.E. Sopper, E.S. Corbett, and D.W. Aurand. 1975. Effects of management practices on water quality and quantity: the Penn State Experimental Watersheds. In: Municipal Watershed Management Symposium Proceedings, USDA Forest Service, General Technical Report, NE-13, pp 32-46.

Mackay, D.S. and L.E. Band. 1997. Forest ecosystem processes at the watershed scale: dynamic coupling of distributed hydrology and canopy growth. Hydrological Processes, 11:1197-1217.

Mader, D.L., W.P. MacConnell, and J.W. Bauder. 1972. The effect of riparian vegetation control and stand density reduction on soil moisture in the riparian zone. University of Massachusetts – Amherst, College of Food and Natural Resources, Agricultural Experiment Station. Research Bulletin 597.

Magill, A. and J. Aber. 1993. Changes in nitrogen mineralization, nitrification and nitrogen leaching in the chronic N plots at Harvard Forest. IN: Long Term Ecological Research at Harvard Forest, Foster, D.R. and D.R. Smith eds., 109 pp.

Malben, G. and J.B. Foote. 1955. Beaver activity and water quality. J. Amer. Water Works Assoc. 47:503-507.

Marchand, P.J. 1987. North woods: an inside look at the nature of foress in the Northeast. Appalachian Mountain Club, Boston, MA.

Maret, T.J., M. Parker, and T.E. Fannin. 1987. The effect of beaver ponds on the nonpoint source water quality of a stream in southwestern Wyoming. Wat. Res. 21(3):263-268.

Margolis, B.E., M.S. Castro, and R.L. Raesly. 2001. The impact of beaver impoundments on the water chemistry of two Appalachian streams. Can. J. Fish. Aquat. Sci. 58: 2271-2283.

Marks, P.L. and F.H. Bormann. 1972. Revegetation following forest cutting: mechanisms for return to steady-state nutrient cycling. Science. 176:914-915.

Marquis, D.A., P.L. Eckert, and P.A. Roach. 1976. Acorn weevils, rodents, and deer all contribute to oak regeneration difficulties in Pennsylvania. USDA, For. Service Research Paper NE-356, 5 pp.

Marquis, D.A., T.J. Grisez, J.C. Bjorkbom, and B.A. Roach. 1975. Interim guide to regeneration of Allegheny hardwoods. USDA Forest Service Gen. Tech. Rep. NE-19.

Marquis, David A. 1991. Uneven-Aged Management in the Cherry-Maple Forest. Proceedings of the Allegheny Society of American Foresters Symposium on Uneven-aged Management.

Martin, C.W. 1988. Soil disturbance by logging in New England - review and management recommendations. Northern Journal of Applied Forestry Vol 5, March, pp 30-34.

Martin, C.W. and R.S. Pierce. 1980. Clearcutting patterns affect nitrate and calcium in streams in New Hampshire. Journal of Forestry. May: 268-272.

Martin, C.W., D.S. Noel, and L.A. Fedrer. 1984. Effects of forest clearcutting in New England on stream chemistry. Journal of Environmental Quality Vol 13, pp 204-210.

Maser, C., S.P. Cline, K. Cromack Jr., J.M. Trappe, and E. Hansen. 1988. What we know about large trees that fall to the forest floor. Chapter 2, in: From the Forest to the Sea: A Story of Fallen Trees. USDA Forest Service, General Technical Report, PNW-GTR-229.

Mather, M. E. 1993. The Quabbin ecosystem: an interdisciplinary ecological review. Final report of the seminar. University of Massachusetts, Department of Forestry and Wildlife Management.

Matthews, J.D. 1989. Silvicultural systems. Oxford University Press, New York, NY.

Mayer, P.M., S.K. Reynolds, M.D. McCutchen, and T.J. Canfield. 2006. Riparian buffer width, vegetative cover, and nitrogen removal effectiveness: a review of current science and regulations. EPA/600/R-05/118. Cincinnati, OH, U.S. Environmental Protection Agency.

McAvoy, D.C. 1989. Episodic response of aluminum chemistry in an acid-sensitive Massachusetts catchment. Water Resources Research. 25(2):233-240.

McColl, J.G. and D.F. Grigal. 1975. Forest fire: effects on phosphorus movement to lakes. Science. 188:1109-1111.

McEvoy, T.J. 2004. Positive impact forestry: a sustainable approach to managing woodlands. Island Press, Washington, D.C. 268 pp.

McInnes, P.F., R.J. Naiman, J.Pastor, and Y.Cohen. 1992. Effects of moose browsing on vegetation and litter of the boreal forest, Isle Royale, Michigan, USA. Ecology. 73(6): 2059-2075.

McKee, W. 1993. Personal communication. Southeastern Forest Experiment Station, U.S.D.A. Forest Service.

McLaren, B.E., S.P. Mahoney, T.S. Porter, and S.M.Oosenbrug. 2000. Spatial and temporal patterns of use by moose of pre-commercially thinned, naturally-regenerating stands of balsam fir in central Newfoundland. Forest Ecology and Management. 113: 179-196.

McManus, K.A., K.S. Shields, and D.R. Souto (eds.). 2000. Proceedings: symposium on sustainable management of hemlock ecosystems in eastern North America: June 22-24, 1999. Durham, N.H. Gen. Tech. Rep 267. Newtown Square, PA: USDA Forest Service, Northeastern Research Station. 237 p. .

McRae, G., and C. J. Edwards. 1994. Thermal characteristics of Wisconsin headwater streams occupied by beaver: implications for brook trout habitat. Trans. Am. Fish. Soc. 123:641-656.

McShea, W.J., and J.H. Rappole. 1997. Herbivores and the ecology of forest understory birds. *In*: The Science of Overabundance: deer ecology and population management. Smithsonian Institution Press. 402pp.

McShea, W.J., H.B. Underwood, and J.H. Rappole. 1997. The science of overabundance: deer ecology and population management. Smithsonian Institution Press. 402 pp.

MDC, Division of Watershed Management. 1988. Water quality report: Quabbin Reservoir and Wachusett Reservoir: watershed monitoring results. Unpublished MDC report.

MDC, Division of Watershed Management. 1991. Quabbin Reservation white-tailed deer impact management plan. Unpublished MDC report.

MDC, Division of Watershed Management. 2002. Sudbury Reservoir Watershed System Public Access Plan Update.

MDC/MWRA. 1991. Watershed protection plan: Quabbin Reservoir and Ware River watersheds. Prepared by Rizzo Assoc. and CH2M Hill. February 28, 1991.

Meentemeyer, R.K. and D.R. Butler. 1999. Hydrogeomorphic effects of beaver dams in Glacier National Park, Montana. Phys. Geo. 20 (5):436-446.

Melillo, J.M., J.D. Aber, P.A. Steudler and J.P. Schimel. 1983. Denitrification potentials in a successional sequence of northern hardwood forest stands. Environmental Biogeochemistry Ecological Bulletin, Stockholm. 35:217-228.

Metts, B. S., J. D. Lanham, and K. R. Russell. 2001. Evaluation of herpetofaunal communities on upland streams and beaver-impounded streams in the upper piedmont of South Carolina. Amer. Midl. Nat. 145.

Metzmaker, J.B. and A.E. Rosquist. 1986. Watershed monitoring to assess the risk of a Giardia lamblia contamination of unfiltered municipal water supplies. International Symposium on Water-Related Health Issues, American Water Resources Association, November, pp 145-151.

Meyer, J.L. and G.E. Likens. 1979. Transport and transformation of phosphorus in a forest stream ecosystem. Ecology. 60(6):1255-1269.

Micks, P., R. Boone and S. Scott. 1994. Abiotic N fixation by forest floor material from the chronic N plots. Abstr. 5th Annual Harvard Forest Ecology Symposium. April 25, 1994.

Miller, D.R., M.J. Focazio, and M.A. Dickinson. 1986. A user's guide to a model for estimating the hydrological effects of land use change (BROOK). Cooperative Extension, University of Massachusetts, University of Connecticut.

Mladenoff, D.J. 1987. Dynamics of nitrogen mineralization and nitrification in hemlock and hardwood treefall gaps. Ecology. 68:1171-1180.

Mladenoff, D.J., M.A. White, J. Pastor, and T.R. Crow, 1993. Comparing spatial pattern in unaltered old-growth and disturbed forest landscapes. Ecological Applications 3(2):294-306.

Monaghan, P., C.B. Shedden, K. Ensor, C.R. Fricker and R.W.A. Girdwood. 1985. Salmonella carriage by herring gulls in the Clyde area of Scotland in relation to their feeding ecology. J. Appl. Ecol. 22:669-680.

Monzingo, D.L., Jr. and C.P. Hibler. 1987. Prevalence of Giardia sp. in a beaver colony and the resulting environmental contamination. J. Wildlf. Dis. 23(4):576-585.

Moore, S.T. 1966. Management of a municipal supply watershed. Symposium of Forest Watershed Management: Practical Aspects. Society of American Foresters, Corvallis, Oregon. pp 61-68.

More, M.E. and J.W. Soper. 1990. GEIR forestland management practices. Massachusetts Department of Environmental Management, EOEEA File Number 6307, 475 pp.

Motzkin, G., D. Foster, A. Allen and J. Harrod. 1994. Vegetation and regional physiographic and disturbance gradients. Abstracts from the 5th Annual Harvard Forest Ecology Symposium. Petersham, M.A.

Mrazik, B.R, D.L. Mader, and W.P. MacConnell. 1980. Integrated watershed management: an alternative for the northeast. Mass. Agricultural Experiment Station, Research Publication Number 664, Univ of Mass, Amherst.

Murdoch, P.S. 1993. Personal communication. USGS Water Res. Div., Albany, N.Y.

Murdoch, P.S., D.A. Burns, and G.B. Lawrence. 1998. Relation of climate change to the acidification of surface waters by nitrogen deposition. Environmental Science and Technology. 32:11, 1642-1647.

Murdoch, P.S. and J.L. Stoddard. 1992. The role of nitrate in the acidification of streams in the Catskill Mountains of New York. Water Resources Research. 28(10):2707-2720.

MWRA/MDC. 1997. Watershed Protection Plan: Sudbury Watershed and Framingham Reservoir No.3. Prepared with assistance of Comprehensive Environmental, Inc., 95 pp + app.

Nadelhoffer, K.J., J.D. Aber and J.M. Melillo. 1984. Seasonal patterns of ammonium and nitrate uptake in nine temperate forest ecosystems. Plant and Soil, 80: 321-335.

Naiman, R.J. and J.M. Melillo. 1984. Nitrogen budget of a subarctic stream altered by beaver (Castor canadensis). Oecologia (Berlin) 62:150-155.

Naiman, R.J., C.A. Johnston and J.C. Kelly. 1988. Alteration of North American streams by beaver. BioScience 38(11):753-762.

Naiman, R.J., G. Pinay, C.A. Johnston, and J. Pastor. 1994. Beaver influences on the long-term biogeochemical characteristics of boreal forest drainage networks. Ecology 75(4):905-921.

Naiman, R.J., J.M. Melillo and J.E. Hobbie. 1986. Ecosystem alteration of boreal forest streams by beaver (Castor canadensis). Ecology 67(5):1254-1269.

National Research Council. 2000. Watershed management for potable water supply: assessing the New York City strategy. National Academy Press, Washington, D.C. 549 pp.

Neville, R. 1996. personal communication. USDA Forest Service, Durham, NH.

NHESP (Massachusetts Natural Heritage and Endangered Species Program). 2006. Massachusetts natural heritage atlas, 12th edition. Printed and distributed by the Massachusetts Division of Fisheries and Wildlife Natural Heritage and Endangered Species Program, Westborough, MA. www.nhesp.org

Nihlgard, B. 1985. The ammonium hypothesis - an additional explanation to the forest dieback in Europe. Ambio. 14(1):2-8.

Nilsson, A. and L. Hakanson. 1992. Relationships between drainage area characteristics and lake water quality. Environ. Geol. Water Sci. 19(2):75-81.

Nolet, B.A., A. Hoekstra, and M.M. Ottenheim. 1994. Selective foraging on woody species by the beaver (Castor fiber), and its impact on a riparian willow. Forest. Biol. Cons. 70:117-128.

Norton, D.A. 1999. Chapter 16, Forest Reserves in M.L. Hunter, Jr. 1999. Maintaining biodiversity in forest ecosystems. Cambridge University Press. 698pp.

Norvell, W.A. and C.R. Frink. 1975. Estimation of potential nutrient enrichment of Lake Wononscopomuc by wild geese. unpubl. manuscript. Conn. Agric. Exp. Station., New Haven.

Novak, M. 1987. In: M. Novak, J.A. Baker, M.E. Obbard, and B. Malloch, eds. Wild furbearer management and conservation in North America. Ontario Ministry of Natural Resources, Toronto. Pp. 283-312

Novotny, V. 2003. Water quality: diffuse pollution and watershed management. John Wiley & Sons, Inc. NY, NY. 864 p.

O'Connor, R.W. 1982. Preventing soil erosion on municipal watersheds. Unpublished paper. S.U.N.Y., Syracuse, NY.

O'Connor. R. and J. Zilligen. 1994. Public access plan for the MDC Sudbury watershed, MDC document, 158 pp.

Odum, E. P. 1969. The strategy of ecosystem development. Science. 164:262-270.

O'Hara, K.L. 1998. Silviculture for structural diversity: a new look at multiaged systems. Journal of Forestry. Volume 96, Number 7, pp. 4-10.

Ollinger, S., J. Aber and C. Federer. 1994. A GIS modeling approach to estimating regional carbon and water balances for the Northeastern U.S. Abstracts from the 5th Annual Harvard Forest Ecology Symposium. Petersham, MA.

Onken, B. (ed.) 2002. Proceedings: hemlock woolly adelgid in the eastern United States.

Orwig, D.A., D.R. Foster, D.L. Mausel. 2002. Landscape patterns of hemlock decline in New England due to the introduced hemlock woolly adelgid. Journal of Biogeography, 29: 1475-1487.

Orwig, D.A. and D.B. Kittredge. 2005. Silvicultural options for managing hemlock forests threatened by hemlock woolly adelgid. IN: U.S.D.A. Forest Service, 2005. B. Onken and R. Reardon, Compilers. Third symposium on hemlock woolly adelgid in the eastern United States. Asheville, North Carolina. February 1-3, 2005. Online: http://www.na.fs.fed.us/fhp/hwa/pub/2005_proceedings/index.shtm

Ottenheimer, D.G. 1992. Hurricane susceptibility and water quality at Quabbin Forest, Massachusetts. M.S. Thesis. State University of New York, Syracuse. 70pp, +app.

OWM. 2004. Hemlock woolly adelgid (*Adelges tsugae Annand*) on DWSP lands: problem extent and proposed management approach. Unpublished agency report.

Parker, D. 1988. Forest endangered: acid rain, ozone damage worsening. Springfield Union. 16 June 1988.

Parsons, W.F.J., D.H. Knight and S.L. Miller. 1994. Root gap dynamics in lodgepole pine forest: nitrogen transformations in gaps of different size. Ecological Applications. 4(2):354-362.

Paterson, K.G. and J.L. Schnoor. 1992. Fate of alachlor and atrazine in a riparian zone field site. Water Environment Research. 64(3):274-283.

Patric, J.H. 1976. Soil Erosion in the eastern forest. J. Forestry Oct., pp 671-677.

Patric, J.H. 1977. Soil erosion and its control in eastern woodlands. Northern Logger and Timber Processor Vol 25, No. 11, May, pp 4-6.

Patric, J.H. 1978. Harvesting effects on soil and water in eastern hardwoods forests. Southern Journal of Applied Forestry 2(3):66-73.

Patric, J.H. 1980. Effects of wood products harvest on forest soil and water relations. Journal of Environmental Quality, 9(1): (73-80).

Patric, J.H. and E.M. Gould. 1976. Shifting land use and the effects on river flow in Massachusetts. Journal of American Water Works Association. (Jan): 41-45.

Patric, J.H, J.O. Evans, and J.D. Helvey. 1984. Summary of sediment yield data from forested land in the United States. J. For. 82(2): 101-104.

Payne, N.F. and F.C. Bryant. 1994. Techniques for wildlife habitat management of uplands. McGraw-Hill, Inc. 840pp.

Peek, J.M., and K.I. Morris. 1998. Status of moose in the contiguous United States. Alces. 34(2): 423-434.

Perkey, A.W., B.L. Wilkens, and H.C. Smith. 1993. Crop Tree Management in Eastern Hardwoods, U.S. Forest Service Publication: NA-TP-19-93.

Peters, N.E. and P.S. Murdoch. 1985. Hydrogeologic comparison of an acidic-lake basin with a neutral-lake basin in the west-central Adirondack Mountains, New York. Water, Air, and Soil Pollution. 26:387-402.

Petersen, C. and G.C. Smith. 1989. Are the forests of Massachusetts in decline?. IN: Current issues in forestry, Cooperative Extension, University of Mass., Amherst, Vol I, No 2, May, 4 pp.

Pickett, S.T.A. and P.S. White, eds.. 1985. The ecology of natural disturbance and patch dynamics. Academic Press Inc., New York, 472 pp.

Portnoy, J.W. 1990. Gull contributions of phosphorous and nitrogen to a Cape Cod kettle pond. Hydrobiologia 202:61-69.

Putz, F.E. and R.R. Sharitz. 1991. Hurricane damage to old-growth forest in Congaree Swamp National Monument, South Carolina, U.S.A. Can. J. For. Res. 21: 1765-1770.

Raup, H.M. 1957. Vegetational adjustment to the instability of site. in Proc. 6th Tech. Meet. 1956 Int. Un. Conserv. Nature Nat. Resources, Edinburgh. pp 36-48.

Reese, K.P. and J.D. Hair. 1976. Avian species diversity in relation to beaver pond habitats in the Piedmont region of South Carolina. Proc. Southeast Assoc. F & W Agencies Conf. 30:437-447.

Reich, P.B. and R.G. Amundson. 1985. Ambient levels of ozone reduce net photosynthesis in tree and crop species. Science. 230:566-570.

Reid, J. 1992. Personal communication. Hampshire College, Amherst, MA.

Reid, W., B.L. Parker, M. Skinner, S. Gouli, and H.B. Teillon. 2002. Insect-killing fungi for management of hemlock woolly adelgid: a review of progress. In: Proceedings: hemlock woolly adelgid in the eastern United States. February 5-7, 2002. B. Onken (ed). Rutgers – the State University of New Jersey, East Brunswick, NJ. 403 p.

Reinhart, K.G. and A.R. Eschner. 1962. Effects on streamflow of four different forest practices in the Allegheny Mountains, J. Geophys. Research. 67:2433-2445.

Reinhert, R.H. and J.A. Hroncich. 1990. Source water quality management. pp. 189-228 IN: F.W. Pontius (ed). Water quality and treatment: a handbook of community water supplies. AWWA. McGraw-Hill.

Remillard, M.M., G.K. Gruendling and D.J. Bogucki. 1987. Disturbance by beaver (Castor canadensis) and increased landscape heterogeneity. Chapt. 6 IN: M.G.Turner (ed), Ecological Studies: Vol 64. Landscape heterogeneity and disturbance. Springer-Verlag, N.Y.

Reuss, J.O. and D.W. Johnson. 1986. Acid deposition and the acidification of soils and waters. Ecological Studies. Springer-Verlag; New York, N.Y.

Rittmaster, R.L. and J.B. Shanley. 1990. Effects of atmospheric wet deposition on the water quality of two streams in the Quabbin Reservoir watershed, central Massachusetts, 1983-85. U.S. Geological Survey. Water-Resources Investigations Report 90.

Rittmaster, R.L. and J.B. Shanley. 1995. Factors affecting water quality and net flux of solutes in two stream basins in the Quabbin Reservoir drainage basin, central Massachusetts, 1983-85. U.S. Geological Survey. Water-Resources Investigations Report 94-4003.

Roberts, M.R. and F.S. Gilliam. 1995. Patterns and mechanisms of plant diversity in forested ecosystems: implications for forest management. *Ecological Applications*, Vol. 5, No. 4, pp. 969-977

Robinson, J.B., H.R. Whiteley, W. Stammers, N.K. Kaushik, and P. Sain. 1979. The fate of nitrate in small streams and its management implications. In: Best management practices for agriculture and silviculture: Proceedings of the 1978 Cornell Agricultural Waste Management Conference, Ann Arbor Science Publishers, pp 247-259.

Rose, J.B. 1988. Occurrence and significance of Cryptosporidium in water. J. Amer. Wat. Works Assoc.:53-58.

Rothacher, J. 1970. Managing forest land for water quality. IN: Proceedings of the Joint FAO/U.S.S.R. international symposium on forest influences and watershed management, Moscow, U.S.S.R. by USDA Forest Service.

Runkle, J. R. 1985. Disturbance regimes in temperate forests. In: The Ecology of Natural Disturbance and Patch Dynamics. S. T. A. Pickett and P. S. White (editors), Academic Press, Orlando, FL, pp. 17-33.

Runkle, J.R. 1982. Patterns of disturbance in some old-growth mesic forests of eastern North America. Ecology 63(5): 1533-1546

Russell, E.W.B. 1983. Indian-set fires in the forests of the Northeastern United States. Ecology. 64: 78-88.

Russell, H.S. 1976. A long, deep furrow: three centuries of farming in New England. University Press of New England. Hanover, N.H. 672 pp.

Russell, K.R., C.E. Moorman, J.K. Edwards, B.S. Metts, and D.C. Guynn, Jr. 1999. Amphibian and reptile communities associated with beaver (Castor canadensis) ponds and unimpounded streams in the piedmont of South Carolina. J. Freshwater Ecol. 14(2):149-160.

S.U.N.Y. 1981. New York river basins special studies: a proposal plan of forestland watershed management for Scoharie watershed. Syracuse, N.Y. Unpublished. (cited in O'Connor, 1982).

Sample, D.W. and M.J. Mossman. 1997. Managing habitat for grassland birds: a guide for Wisconsin. Wis. Dept. Nat. Res. 154pp.

Satterlund, D.R. and P.W. Adams. 1992. Wildland watershed management. 2nd edition. John Wiley & Sons, Inc. New York, N.Y.

Savill, P.S. 1983. Silviculture in windy climates. Forestry Abstracts. 44(8):473-488.

Schindler, D.W. 1988. Effects of acid rain on freshwater ecosystems. Science. 239:149-157.

Schindler, D.W., R.W. Newbury, K.G. Beaty, J. Prokopowich, T. Ruszczynski, and J.A. Dalton. 1980. Effects of a windstorm and forest fire on chemical losses from forested watersheds and on the quality of receiving streams. Canadian Journal of Fisheries Aquatic Science. 37:328-334.

Schofield, C.L., J.N.Galloway, and G.R. Hendry. 1985. Surface water chemistry in the ILWAS Basins. Abstract. Water, Air, and Soil Pollution. 26:403-423.

SCS. 2004. Scientific Certification System's "Certification Evaluation Report for the Natural Forests Managed by the Commonwealth of Massachusetts". Online: http://www.mass.gov/envir/forest/pdf/forestgreencertreport.pdf . 175 pp.

Schueler, T. 1987. Controlling urban runoff: a practical manual for planning and designing urban BMPs. Prepared for the Washington Metropolitan Water Resources Planning Board.

Scudder, J.H. 1949. A preliminary study of forest succession in central New England. Masters thesis, Harvard University. 69 pp.

Searcy, K.B. 1995. Quabbin rare plant survey, June-August, 1995. Final report to MDC.

Searcy, K.B. 1996. 1996 rare plant survey: Quabbin,Ware River,Wachusett, and Sudbury watersheds. Final report to MDC.

Shanley, J.B. 1993. Personal communication. United States Geological Survey.

Sheehan, K.C. 1982. Development of environmental impact criteria for recreational use of the Quabbin Reservoir. Master's thesis, Dept. Civil Engineering, University of Massachusetts. 95 pp.

Shepard, J.P., M.J. Mitchell, T.J. Scott, and C.T. Driscoll. 1990. Soil solution chemistry of an Adirondack spodosol: lysimetry and N dynamics. Canadian Journal of Forest Resources, 20:818-824.

Skeffington, R.A. and E.J. Wilson. 1988. Excess nitrogen deposition: issues for consideration. Environmental Pollution. 54:159-184.

SmartWood. 1997. Certification assessment report of the Metropolitan District Commission's Quabbin Reservoir lands, Commonwealth of Massachusetts. National Wildlife Federation, Northeast Natural Resource Center and The Rainforest Alliance's SmartWood Program. June 1997, 60 pp.

Smith, D.M., B.C. Larson, M.J. Kelty, P.M.S.Ashton. 1997. The practice of silviculture: applied forest ecology. John Wiley and Sons, New York, NY. 560 pp.

Smith, D.M. 1986. The practice of silviculture, eighth edition. John Wiley and Sons, New York, NY. 527 pp.

Smith, M.E., C.T. Driscoll, B.J. Wyskowski, C.M. Brooks and C.C. Cosentini. 1991. Modification of stream ecosystem structure and function by beaver (Castor canadensis) in the Adirondack Mountains, New York. Can. J. Zool. 69:55-61.

Smith, W.H. 1981. Air pollution-effects on the structure and function of the temperate forest ecosystem. In: Air pollution and forests. Springer-Verlag, New York. 379 pp.

Snodgrass, J.W. 1997. Temporal and spatial dynamics of beaver-created patches as influenced by management practices in a south-eastern North American landscape. J. Appl. Ecol. 34:1043-1056.

Snodgrass, J.W. and G.K. Meffe. 1998. Influence of beavers on stream fish assemblages: effects of pond age and watershed position. Ecology. 79(3):928-942.

Snow, D.R. 1980. The archaeology of New England. Academic Press, New York, N.Y.

Snyder, E.J., and K. Bontaitis. 2001. Moose fact sheet. University of New Hampshire Cooperative Extension. 4 pp.

Sorrie, B.A. 1989. Massachusetts flora: a review of current distribution and conservation of rare species. Rhodora 91:116-120.

Speranza, D.E. 1988. An investigation of Giardia lamblia in the Quabbin and Wachusett reservoirs. M.S. Thesis, University of Massachusetts, Amherst.

Spurr, S.H. and B.V. Barnes. 1980. Forest ecology (third edition). John Wiley and Sons, Inc. New York, NY. 687 pp.

Standridge, J.H., J.J. Delfino, L.B. Kleppe and R. Butler. 1979. Effect of waterfowl (Anas platyrhynchos) on indicator bacteria populations in a recreational lake in Madison, Wisconsin. Appl. Envir. Microbiol. 38:547-550.

Stednick, J.D. 2000. Timber management. In: Dissmeyer, G.E., ed. Drinking water from forests and grasslands; A synthesis of the scientific literature. U.S.D.A. Forest Service, General Technical Report SRS-39. Ashville, N.C.: 103-119.

Stekl, P.J. 1985. A hydrogeologic investigation of two small watersheds of the eastern Quabbin basin. Masters Thesis, University of Massachusetts.

Stephens, E.P. 1956. The uprooting of trees: a forest process. Proceedings of the Soil Science Society of America. 20:113-116.

Stoddard, J.L. 1991. Trends in Catskill stream water quality: evidence from historical data. Water Resources Research. 27(11):2855-2864.

Stone, E.L. 1973. The impact of timber harvest on soils and water. In: Report of the President's Advisory Panel on Timber and the Environment, April, pp 427-467.

Stone, E.L., W.T. Swank, and J.W. Hornbeck. 1979. Clearcutting versus alternative timber harvest and regeneration systems: impacts on soils and streamflow in the eastern deciduous region. USDA Forest Service.

Storey, H.C. and I.C. Reigner. 1970. Vegetation management to increase water yields. In: Proceedings of the Symposium on Interdisciplinary Aspects of Watershed Management, August 3-6, Montana State University, American Society of Civil Engineers, New York, pp 271-293.

Stuart, G.W. and P.J. Edwards. 2006. Concepts about forests and water. Northern Journal of Applied Forestry 23:1, 11-19.

Suurballe, N.C. 1992. Effects of a wetland on quality of Natty Pond Brook, Massachusetts, 1985-86. U.S. Geological Survey. Water-Resources Investigations Report 91-4144. 52 pp.

Swank, W.T. 1972. Water balance, interception, and transpiration studies on a watershed in the Puget lowland region of western Washington. Ph.D. Dissertation, University of Washington, Seattle.

Swank, W.T., J.B. Waide, D.A. Crossley, Jr., and R.L. Todd. 1981. Insect defoliation enhances nitrate export from forest ecosystems. Oecologia 51:297-299.

Tamm, C.O. 1991. Nitrogen in terrestrial ecosystems: questions of productivity, vegetational changes, and ecosystem stability. Ecological Studies. Springer-Verlag, New York, N.Y. 116p.

Thompson, C. H. and T.D. Kyker-Snowman. 1989. Evaluation of non-point source pollution problems from crossing streams with logging equipment and off-road vehicles in Massachusetts: 1987-1988. Report produced as part of Generic Environmental Impact Report on Forest Management in Massachusetts. Massachusetts Department of Environmental Management.

Thompson D.Q. and R.H. Smith 1970. The forest primeval in the Northeast--a great myth? In: Proc Ann Tall Timbers Fire Ecology Conf 10: 255-265, R. Komarek, ed.. Tallahassee, FL.

Thompson, F.R., and R.M. DeGraaf. 2001. Conservation approaches for woody, early successional communities in the eastern United States. Wild. Soc. Bull. 29(2):483-494.

Thompson, F.R. III and D.R. Dessecker. 1997. Management of early successional communities in central hardwood forests. USDA For. Serv. Gen. Tech. Rep. NC-195. 33pp.

Thornthwaite, C.W., J.R. Mather, and D.B. Carter. 1958. Three water balance maps of eastern North America. Resources for the Future, Inc. Washington, D.C.

Thorson, R.M. 2002. Stone by stone: the magnificent history in New England's stone walls. Walker and Company, New York, NY. 287 pp.

Trani, M.K., R. T. Brooks, T. L. Schmidt, V. A. Rudis, and C.M. Gabbard. 2001. Patterns and trends of early successional forests in the eastern United States. Wildl. Soc. Bull. 29(2).

Trimble, G.R. Jr., J.H. Patric, J.D. Gill, G.H. Moelleer, and J.N. Kochenderfer. 1974. Some options for managing forest land in the central Appalachians. USDA Forest Service, General Technical Report NE-12, 42 pp.

Trombulak, S.C., and C. Frissell. 2000. A review of the ecological effects of roads on terrestrial and aquatic ecosystems. Conservation Biology 14: 18-30.

Tubbs, C.H., R.M. DeGraaf, M. Yamasaki and W.M. Healy. 1987. Guide to wildlife tree management in New England northern hardwoods. USDA For. Serv. Gen. Tech. Rep. NE-118.

Tyrrell, L.E. and T.R. Crow. 1994. Structural characteristics of old-growth hemlock-hardwood forests in relation to age. Ecology 75(2):370-386.

Tzipori, S. 1983. Cryptosporidiosis in animals and humans. Microbiol. Rev. 47:84.

U.S. E.P.A. 1993. Handbook: urban runoff pollution prevention and control planning. U.S. publication no. EPA/625/R-93/004.

U.S.D.A. Forest Service, 2005. B. Onken and R. Reardon, Compilers. Third symposium on hemlock woolly adelgid in the eastern United States. Asheville, North Carolina. February 1-3, 2005. Online: http://www.na.fs.fed.us/fhp/hwa/pub/2005_proceedings/index.shtm

U.S.D.A. Forest Service. 1991. Riparian forest buffers; function and design for protection and enhancement of water resources. NA-PR-07-91.

U.S.D.A. Forest Service. 1990. Silvics of North America. Vol.1 Conifers, Vol.2 Hardwoods. Agricultural Handbook 654. Vol.1 675 pp; Vol.2 877 pp.

United States Geological Survey (USGS). 2000. http://www.ma.water.usgs.gov/

Van Miegroet, H. and D.W. Johnson. 1993. Nitrate dynamics in forest soils. IN: Nitrate: processes, patterns and management. T.P. Burt, A.L. Heathwaite, S.T. Trudgill, eds. John Wiley and Sons, New York, N.Y. 444p.

Vecellio, G.M., R.D. Deblinger, and J.E. Cardoza. 1993. Status and management of moose in Massachusetts. Alces. 29: 1-7.

Vellidis, G. 1994. Restoration of riparian wetlands: a case study. In: Proceedings: Riparian Buffer Zones Conference. Society of Soil Scientists of Southern New England.

Vellidis, G., R. Lowrance, and M.C. Smith. 1994. A quantitative approach for measuring N and P concentration changes in surface runoff of a restored riparian wetland forest. Wetlands 14(2):73-81.

Veneman, P.L.M. 1984. Evaluation of the buffering capacity of Massachusetts soils to negotiate the impact of acid deposition on water quality. Completion Report to the Massachusetts Dept. of Environmental Quality Engineering Division of Air Quality control. University of Massachusetts at Amherst.

Vernegaard, L., R. Hopping, and D. Reid. 1998. Ecological management of grasslands: guidelines for managers. The Trustees of Reservations, Massachusetts. 20pp.

Verry, E.S. 1986. Forest harvesting and water: the Lakes States experience. Water Resources Bulletin. 22(6):1039-1047.

Vitousek, P. M., W.A. Reiners, J.M. Melillo, C.C. Grier, and J.R. Gosz. 1981. IN: Stress effects on natural ecosystems. pp. 115-127.

Vitousek, P.M. 1977. The regulation of element concentrations in mountain streams in the northeastern U.S. Ecol. Monographs, Vol. 47, pp 65-87.

Vitousek, P.M. 1985. Community turnover and ecosystem nutrient dynamics. In: Pickett, S.T.A. and P.S. White., eds, The Ecology of Natural Disturbance and Patch Dynamics. Academic Press Inc., New York, pp 325-333.

Vitousek, P.M. and J.M. Melillo. 1979. Nitrate losses from disturbed forests: patterns and mechanisms. Forest Science Vol. 25(4).

Vitousek, P.M. and W.A. Reiners. 1975. Ecosystem succession and nutrient retention: a hypothesis. Bioscience 25:376-381.

Vitousek, P.M., J.R. Gosz, C.C. Grier, J.M. Melillo, and W.A. Reiners. 1982. A comparative analysis of potential nitrification and nitrate mobility in forest ecosystems. Ecol Monographs Vol 52(2), pp 155-177.

Vitousek, P.M., J.R. Gosz, C.C. Grier, J.M. Melillo, W.A. Reiners and R.L. Todd. 1979. Nitrate losses from disturbed ecosystems. Science. 204:469-474.

von Oettingen, S.L. 1982. A survey of beaver in central Massachusetts for Giardia lamblia. M.S. Thesis, University of Massachusetts, Amherst. 57 pp.

Walters, C.J. 1986. Adaptive management of renewable resources. MacMillan Publishing Company, New York, NY.

Wandle, S.W. n.d. Estimating peak discharges of small, rural streams in Massachusetts. U.S. Geological Survey Water-Supply Paper 2214. 25 pp.

Waring, R.H. and W.H. Schlesinger. 1985. Forest ecosystems: concepts and management. Academic Press, Inc. Harcourt Brace Jovanovich. New York, N.Y.

Webster, B. 1983. The shy beaver: powerful effects on ecology seen in new research. N.Y. Times, Tues. Jan. 11.

Welsch, D.J. 1991. Riparian forest buffers; function and desigh for protection and enhancement of water resources. U.S.D.A. Forest Service, Radnot, PA. Pub No. NA-PR-07-91.

Whigham, D.F., C. Chitterling, and B. Palmer. 1988. Impacts of freshwater wetlands on water quality: a landscape perspective. Environmental Management. 12(5):663-671.

White, L.A., Jr., A.R. Eschner, S.J. Riha, and F.N. Swader. Forest soil and water relationships; New York State forest resources assessment report no. 11. New York State Department of Environmental Conservation, Division of Lands and Forests, Forest Resources Planning Program, 1980.

Whitney, G.G. 1994. From coastal wilderness to fruited plain: a history of environmental change in temperate North America, 1500 to the present. Cambridge University Press. Cambridge, England. 451 p.

Wilde, S.A., C.T. Youngberg and J.H. Hovind. 1950. Changes in composition of ground water, soil fertility and forest growth produced by the construction and removal of beaver dams. J. Wildl. Manage. 14(2):123-128.

Wilen, B.O., W.P. McConnell and D.L. Mader. no date. The effects of beaver activity on water quantity and quality. Unpubl. manuscript. Univ. of Mass., Amherst, MA.

Williams, T.M. and A.C. Mace Jr. 1974. Effects of alternative harvesting systems on cycling of major nutrients in a forest soil. In: Proceedings of the Society of American Foresters.

Williamson, S. J. n.d.. Forester's guide to wildlife habitat improvement. Univ. New Hampshire, Coop. Ext. 41pp.

Wischmeier, W.H. and D.D. Smith. 1965. Predicting rainfall-erosion losses from cropland east of the Rocky Mountains. Agr. Handbook 287. USDA, Washington, DC.

Woo, M-K. and J.M. Waddington. 1990. Effects of beaver dams on subarctic wetland hydrology. Arctic. 43(3):223-230.

Wraight, S.P., M.A. Jackson, and S.L. deKock. 2001. Production, stabilization and formulation of fungal biocontrols agents, pp. 253-288. In Butt, T.M., C.W. Jackson, and N. Magan (eds.), *Fungi as Biocontrol Agents: Progress, Problems and Potential.* Pp. 253-288. CABI Publishing, New York.

Wright, R.F. 1976. The impact of forest fire on the nutrient influxes to small lakes in northeastern Minnesota. Ecology. 57:649-663.

Yeakley, J.A., D.C. Coleman, B.L. Haines, B.D. Kloeppel, J.L. Meyer, W.T. Swank, B.W. Argo, J.M. Deal, and S.F. Taylor. 2003. Hillslope nutrient dynamics following upland riparian vegetation disturbance. Ecosystems (2003) 6:154-167.

Yeo, J. 1991. The future role of the Sudbury Reservoirs and watershed in the MDC/MWRA water supply system: a study of alternatives. MWRA unpublished report, 54 p.

Yorks, T.E. 2002. Influence of hemlock mortality on soil water chemistry and ground flora. In Proceedings: hemlock woolly adelgid in the eastern United States. February 5-7, 2002. B. Onken (ed). Rutgers – the State University of New Jersey, East Brunswick, NJ. 403 p.

Yorks, T.E., J.C. Jenkins, D.J. Leopold, D.J. Raynal, and D.A. Orwig. 2000. Influences of Eastern hemlock mortality on nutrient chemistry. IN:McManus, K.A., K.S. Shields, D.R. Souto, eds. 2000. Proceedings: symposium on sustainable management of hemlock ecosystems in easter North America; 1999 June 22-24; Durham, N.H. Gen. Tech. Rep. 267. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 237 p.

Yoshida, S. and M. Ichikuni. 1989. Role of forest canopies in the collection and neutralization of airborne acid substances. The Science of the Total Environment. 84:35-43.

Yuretich, R.F., ed. 1992. Impacts of acid deposition on watersheds of the Quabbin Reservoir. Water Resources Research Center, University of Massachusetts, Pub. No. 166. 229 pp.

Yuretich, R.F., P.J. Stekl and S.J. Pohanka. 1986. Hydrogeology and mineral weathering reactions in watersheds of Central Massachusetts. Water Resources Research Center, University of Massachusetts, Pub. No. 152. 85 pp.

Zhou, G., S. Lui, Z. Li, D. Zhang, X. Tang, C. Zhou, J. Yan, and J. Mo. 2006. Old-growth forests can accumulate carbon in soils. Science. 324:1417

9 Glossary of Terms

Listed in alphabetical order below are terms and definitions that DWSP uses throughout various watershed land management plans. Specific sources of definitions are shown in parenthesis, where applicable.

age class: (from Society of American Foresters, 1971. Terminology of forest science, technology, practice, and products.) one of the intervals, commonly 10 years, into which the age range of tree crops (and sometimes other vegetation) is divided for classification or use.

aggradation: (from Bormann and Likens, 1979. Pattern and process in a forested ecosystem.) in Northern Hardwoods, a period of more than a century when the ecosystem accumulates total biomass reaching a peak at the end of the phase; preceded by the reorganization phase and followed by the transition phase.

advance regeneration: in silvicultural terms, young trees that have become established naturally in a forest, in advance of regeneration cutting; may become established following "preparatory" cuts.

allogenesis: changes in an ecological community primarily through periodic, acute, external (exogenous) disturbances, such as storms. These changes generally reset the successional progression of the community.

area inch; acre inch: used to describe changes in water yield from a given area of land; for instance, if a change in vegetation results in an increase of one acre inch in water yield, this translates to 43,560sq ft x 1/12ft = 3,630 cubic feet per acre; 3,630ft^3 / 7.5 gals per ft^3 = 484 gallons additional yield per acre. Area inch is translated to percent water yield increase by dividing area inch by total inches of yield. For example 40 inches of precipitation generally yields 50%, or 20 inches of discharge, therefore a 2 area inch increase in yield on this watershed is a 10% increase (2/20).

autogenesis: changes in an ecological community primarily through the regular, internal processes of growth, competition, and senescence, which are general endogenous (within community) forces that result in a steady successional progression of the community.

basin; sub-basin: the land area from which all water flows to a single, identified water source, such as a stream, a river, or a reservoir. Sub-basin is used to refer to the basin of a tributary or lower *order* stream (the higher the order, the greater the area drained).

basal area: the area in square feet of the cross section of a tree taken at 4.5 feet above the ground.

"beaver pipe"; flow control pipe: generally a length of culvert that is extended into a beaver pond and at or near the top of the beaver dam, in order to maintain the pond level at a particular level.

Best Management Practices, BMPs: in natural resources management, refers to a set of standards that have been designed for an activity, and often a region, to protect against degradation of resources during management operations.

biological diversity (biodiversity): a measure, often difficult to quantify, of the variety and abundance of plant and animal species within a specified area, at the genetic, species, and landscape level of analysis. The 1992 UN Convention on Biological Diversity defined biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".

biomass: (SAF) the total quantity of living organisms of one or more species per unit area (species biomass) or of all the species in a community (community biomass)

Conservation Management Practices, CMPs: in natural resources management, refers to a set of standards that have been designed for an activity, and often a region, to protect against degradation of resources during management operations. Also known as Best Management Practices, BMPs.

conservation restriction; conservation easement; CR: a legal agreement between a landowner and another party whereby the landowner deeds the rights to development of the property to the other party, but retains ownership of the land and other rights to its use. Specific agreement varies, but the general result is to protect land from conversion to new uses without requiring transfer of ownership; DWSP also limits or retains the right to approve certain agricultural and silvicultural practices in its CRs.

Continuous Forest Inventory (C.F.I.): an extensive method of forest inventory in which permanent sample plots are remeasured at periodic intervals to determine forest growth and condition; DWSP's CFI is composed of 1/5 acre permanent plots, located on a 1/2 mile grid, and remeasured every 10 years.

cutting cycle: the frequency with which silvicultural cuttings are conducted in any given area; cutting cycle is a subunit of "rotation," which is determined either by the maximum life of the existing overstory, or by a predetermined maximum age imposed on the area.

Cryptosporidium: A coccidian protozoan parasite found in humans and various wild and domestic animals that can be transmitted via water and often causes serious intestinal illness. While the epidemiology and transmission of *Cryptosporidium* are similar to *Giardia*, its oocysts are smaller that the cysts of other protozoa, and thus may be more difficult to remove from water supplies.

diameter at breast height; DBH: the diameter of a tree, outside the bark, taken at 4.5' above the ground, generally in inches and fractions.

diverse/diversity: in this plan, the term is most often used to refer to forest composition, and refers to both height or size diversity in trees, seeking a minimum of three distinct layers (understory, midstory, and overstory), and to diversity of species composition, with a general goal of avoiding monocultures and working to include components of hemlock, pine, oak, birch, and maple throughout the forest.

disturbance-sheltered: areas that based on slope and aspect are physically "sheltered" from the influence of a catastrophic New England hurricane blowing from the southeast, based on a model developed at the Harvard Forest; the most sheltered areas are steep slopes facing northwest.

edge effect: this term has traditionally been used to describe the increased richness of flora and fauna found where two habitat types or communities meet. More recently, the term has also been used to refer to the increased predation and brood parasitism that often occurs near these boundaries.

endogenous disturbance: disturbance that originates within the ecological community. For example, a single tree that succumbs to a root-rot fungus and falls to the ground, breaking off several other trees on the way, creates an endogenous disturbance. While the proximal cause of the treefall may be wind or accumulation of snow and ice, the primary cause is still considered endogenous in this instance. (see exogenous disturbance below)

even-aged: (SAF) an area of forest composed of trees having no, or relatively small, differences in age. NOTE: By convention the maximum difference admissible is generally 10 to 20 years, though with rotations of 100 years or more, differences up to 30% of the rotation may be admissible.

exogenous disturbance: disturbance that originates from forces outside of the ecological community. For example, storms that carry high winds can cause large-scale treefall well in advance of normal senescence and decay. The cause of the disturbance is therefore considered exogenous. (see endogenous disturbance above)

feller-buncher; feller-buncher-processor: logging machines that grasp a tree to be cut or "felled," sever it at the stump with either a saw or hydraulic shears, and directionally drop it to the ground. Some machines can accumulate, or "bunch" several trees before releasing them. The most complex machines are also capable of delimbing and sawing trees into predetermined lengths (processing).

forest canopy: (SAF) the more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent trees and other woody growth.

forest fragmentation: the separation of a previously contiguous forested area into discontinuous patches or "fragments." These fragments are less useful to wildlife that require large contiguous habitats. Fragmentation by suburban development is likely to be detrimental to "deep woods" species, while the simple break imposed by an access road is not often an impediment.

forwarder: a logging machine used to "forward" logs from the woods to a landing. A forwarder differs from a skidder in that the logs are hydraulically loaded onto the machine and carried, rather than skidded through the woods.

G.I.S.: Geographic Information System - a computer-based analysis and mapping system for spatially-linked data sets.

***Giardia*:** A protozoan parasite found in humans and various wild and domestic animals that can be transmitted via water and often causes serious intestinal illness.

group selection, or small group selection: a cutting in which a roughly homogenous group of overstory trees is removed at the same time, and regeneration is either initially established or released as a result. Groups that, when cut, leave openings with diameters that exceed twice the height of the surrounding trees (and therefore contain areas not under the influence of those trees) are generally referred to as "patches".

hurricane exposure ("exposed," "intermediate," "sheltered"): generally used in DWSP management plans to mean physical exposure of a site to catastrophic hurricane winds, those coming from the southeast. Research at the Harvard Forest in Petersham, MA provides a model of the impact of this typical New England hurricane, which includes slope and aspect. Actual damage will depend on the type and size of vegetation present.

intermediate cut: cutting of trees in a stand during the period between establishment and maturity. Objectives may include the improvement of vigor by reducing competition or the manipulation of species composition. Regeneration may occur following intermediate cuts, but it is incidental to the objective of intermediate cutting.

irregular shelterwood: similar to the shelterwood silvicultural system except that overstory removals are protracted, taking as long as half the rotation, so that the resulting new stand is quite uneven-aged (wide intervals between the oldest and youngest trees) and mimics the multi-storied effect of strictly uneven-aged systems.

log landing; landing: a clearing of variable size to which logs, pulp, and/or firewood are skidded or forwarded during a logging operation, in order to facilitate their processing or further transport by truck.

mast: the fruit and seeds of trees and shrubs. Mast constitutes an important food source for many wildlife species.

milacre: one-thousandth of an acre**.**

mineral soil: any soil consisting primarily of minerals (sand, silt, and clay), rather than organic matter.

multi-aged: a forest that contains more than a single age class and may contain many different age classes not necessarily in balanced proportions. The absence of strict balancing of age classes distinguishes these forests from true "uneven-aged" forests.

multi-storied or multi-layered forest: a forest containing a distinct understory, midstory, and overstory. From a watershed perspective, these layers provide, respectively, immediate response to disturbance, vigorous uptake of nutrients, and deep filtration of air-borne and precipitative pollutants.

naturally managed: the results of a deliberate decision to allow natural disturbances and processes prevail by adopting a minimal management approach that protects forests from development or other land use changes and possibly human-caused fire, but which includes vegetation management only where it clearly counteracts a negative result from previous human disturbances.

old-growth: various definitions, but one definition in Massachusetts is that old-growth must contain at least four acres in which the dominant trees are late-successional species, have reached at least half the potential maximum age of the species with a few trees at or near that age (e.g., birches/maples at 300 years or hemlocks at 400), have late-successional tree regeneration present, and show little or no evidence of human or large-scale natural disturbance during the current stand's development.

patch cut: a regeneration opening in the forest of various sizes but in which some part of the opening is not under the influence of the surrounding trees. All of the trees in the designated area are cut. A patch cut is a small clearcut, but one which removes only a fraction of a complete stand, resulting in a multi-aged stand once the opening has regenerated.

preparatory cutting: (SAF) removing trees near the end of a rotation so as to open the canopy and enlarge the crowns of seed bearers, with a view to improving conditions for seed production and the establishment of natural regeneration.

protected: refers to areas of the watershed that, according to the Harvard Forest model of hurricane disturbance, would suffer minimal damage from the recurrence of a hurricane similar to that of 1938, due primarily to topography and orientation.

protection forest: (SAF) an area, wholly or partly covered with woody growth, managed primarily to regulate stream flow, maintain water quality, minimize erosion, stabilize drifting sand, or to exert any other beneficial forest influences

regeneration: recently established tree growth, generally smaller than one inch dbh; also, the process of establishing this growth, as in "bring about the regeneration of a forest area".

regeneration cut: (SAF) any removal of trees intended to assist regeneration already present or to make regeneration possible.

riparian: pertaining to the bank of a stream or other water body; (SAF) vegetation growing in close proximity to a watercourse, lake, swamp, or spring, and often dependent on its roots reaching the water table.

rotation: in conventional forestry, rotation is (SAF) the planned number of years between the formation or regeneration of a crop or stand and its final cutting at a specified stage of maturity. In the selection system of uneven-aged management, however, the concept of a rotation is replaced with the average age of trees removed to initiate regeneration.

salvage; salvage cutting: the removal of trees damaged by fire, wind, insects, disease, fungi, or other injurious agents before their timber becomes worthless. In some situations, the motivation is the reduction of fuel loading and fire hazard. Sanitation cutting is related, but is a proactive removal of diseased or highly susceptible trees in order to slow or halt the spread of a disease or other destructive agent.

seep: a wet area, generally associated with groundwater seepage, which is important to wildlife because it remains unfrozen, and generally uncovered, during periods when the ground is otherwise snow-covered, which makes it easier for wildlife to forage for seeds.

shelterwood: (SAF) mostly even-aged silvicultural systems in which, in order to provide a source of seed, protection for regeneration, or a specific light regime, the overstory (the shelterwood) is removed in two or more successive shelterwood cuttings, the first of which is ordinarily the seed cutting (though it may be preceded by a preparatory cutting) and the last of which is the final cutting, while any intervening cuttings are termed removal cuttings. Note that where adequate regeneration is already present, the overstory may be removed in one cutting, resulting in a method referred to as a one-cut shelterwood.

silviculture: (SAF) generally, the science and art of cultivating (i.e., growing and tending) forest crops, based on a knowledge of silvics (the study of the life history and general characteristics of forest trees and stands, with particular reference to environmental factors affecting growth and change). More particularly, silviculture is the theory and practice of controlling the establishment, composition, constitution, and growth of forests.

site: in forestry, the combination of environmental factors that affect the ability of a species to grow and persist, including at least soil characteristics, aspect, altitude and latitude, and local climate. Sites are often classified by the ability of specific trees to grow on them.

site index: the ability of a given site to grow a given species. As height growth is generally not density dependent, a common forestry site index is the height to which a given species will grow on the site in fifty years (so that a site with a Red Oak site index of 65 will grow Red Oak to that height in fifty years).

site preparation: in silviculture, any of a variety of treatments of a site that are intended to enhance regeneration success. A common goal of these treatments is to remove enough of the accumulated organic layers above the mineral soil so as to expose that soil and enhance the ability of seeds that fall on it to germinate and grow. The simple skidding of logs is an incidental, and often sufficient, site preparation.

site-suited: species that have evolved to take advantage of a particular type of site. Where species are planted on other sites, they may succumb prematurely to disturbance or disease. Red pine grows and persists well on deep, sandy soils, where root rots are less common, but may become excessively prone to wind and or root rotting diseases on the moist agricultural soils on which they were typically planted.

skidder: logging machine used to "skid" logs from the woods to a landing or a forwarder road. Logs are either winched by cable to the skidder (cable skidder), or lifted on one end by a hydraulic grapple (grapple skidder), and then dragged.

stand: (SAF) a community of trees possessing sufficient uniformity as regards composition, constitution, age, spatial arrangement, or condition to be distinguishable from adjacent communities.

steady state: (Bormann and Likens, 1979. p.4) "For the ecosystem as a whole, over a reasonable period of time gross primary production equals total ecosystem respiration, and there is no net change in total standing crop of living and dead biomass".

stocking: in forestry, the extent to which a site is occupied by trees compared to the maximum occupation possible at a given stand age; a relative measure of stand density. Most commonly measured as basal area per acre, stocking is often related directly to crown closure, as a site is considered fully occupied when crown closure is complete (when each crown has grown to touch all adjacent ones). As crowns can be of very different sizes among species and tree ages within stands, average diameter (dbh) and total number of trees of a "fully stocked" site is variable.

stream order: a classification of streams within watersheds. Small streams at the uppermost level of stream systems are labeled "first-order"; two first-order streams join to form a "second-order" stream; two second-order streams join to form a "third-order" stream; etc.

succession: (SAF) the gradual supplanting of one community of plants by another, the sequence of communities being termed a "sere" and each stage "seral." Succession is "primary" (by "pioneer species") on sites that have not previously borne vegetation, "secondary" after the whole or part of the original vegetation has been supplanted; "allogenic" when the causes of succession are external to and independent of the community (e.g., a storm, or climate change), and "autogenic" when the developing vegetation is itself the cause. "Early succession" generally refers to the pioneer stages and species that follow disturbance, while "late succession" refers to stages and species that occur as an area continues to develop undisturbed for long periods.

thinning: an intermediate silvicultural treatment, generally with the goal of altering the forest composition and/or improving the growing conditions for the residual trees, regardless of associated regeneration effects. Most thinnings leave stands considered to be fully stocked, i.e., capable of fully occupying the site a short while after the thinning has been completed.

turbidity: a water quality measure that is most commonly derived by measuring the proportion of a given amount of light that is deflected by suspended/dissolved sediments in a water sample, giving an indirect measure of these sediments. Most common unit is the nephelometric turbidity unit, NTU.

uneven-aged: (SAF) a forest, crop, or stand composed of intermingling trees that differ markedly in age. By convention, a minimum difference between tree ages of 25% of the rotation age is generally accepted. Some texts require a minimum of three distinct age classes for a stand to qualify as "uneven-aged.". Uneven-aged silviculture, when fully applied, results in balanced age classes. Mixed-age class forests in which no attempt is made to balance age classes is referred to simply as "multi-aged forest".

vernal pool: a temporary body of fresh water that provides crucial habitat for several vertebrate and many invertebrate species of wildlife, but does not support fish populations.

wetland: generally refers in DWSP land management plans to areas defined as "wetlands" by M.G.L. C.131 § 40 (the "Wetlands Protection Act") and 310 C.M.R. 10.00 (the "Wetlands Protection Regulations"), updated as these are revised.

10 Appendices

10.1 Appendix I: 2004 MWRA / DCR MOU

This Memorandum of Understanding ("MOU") sets forth the agreement between the Commonwealth of Massachusetts Department of Conservation and Recreation ("DCR") and the Massachusetts Water Resources Authority ("MWRA") concerning the coordination and implementation of their respective responsibilities established by statute, administrative and court action, and by agreement in regard to the protection, construction, operation, maintenance and improvement of water supply resources, facilities, and infrastructure within the watershed and waterworks systems

See http://www.mass.gov/dcr/waterSupply/watershed/documents/2004dcrmwraMOU.pdf for the complete, 31 page text of this MOU.

10.2 Appendix II: Legislation

10.2.1 Acts of 1972 Chapter 737 (the Kelley-Wetmore Act)

Chapter 737: An act providing for the conservation and regulation of certain lands under the control of the Metropolitan District Commission.

Be it enacted as follows:

SECTION 1. In this act, the following words and phrases, unless otherwise expressly provided or the context otherwise provides, shall have the following meanings:

"Commission", the metropolitan district commission.

"Commissioner", the commissioner of the metropolitan district commission

"Ware river watershed", those parcels of land under the control of the commission and being situated wholly or partly in the towns of Rutland, Oakham, Barre, Hubbardston, Templeton and Princeton and being shown on plan of land entitled "Ware River Watershed, General Plan", dated November 22, 1965, Metropolitan District Commission, Commonwealth of Massachusetts, filed in the office of the commission.

"Quabbin reservoir area", those parcels of land including the Prescott Peninsula, so-called, contiguous to the reservoir under the control of the commission and presently lying within the bounds of Routes 9, 32, 32A, 122 and 202 and being situated wholly or partly in the towns of Pelham, Belchertown, Ware, Hardwick, Petersham, New Salem and Shutesbury, and being shown on plan of land entitled "General Plan of Quabbin Reservoir Watershed, dated February 18, 1959, Metropolitan District Commission, Water Division, Quabbin Section, Commonwealth of Massachsutts", filed in the office of the commission.

"District", the combined lands identified in this act as the Ware river watershed and the Quabbin reservoir area, which are a portion of the total lands comprising the Quabbin section of the metropolitan water district.

SECTION 2. The natural ecology of the district shall be maintained, and it shall be conserved in its present degree of wilderness character and shall be protected in its flora and fauna in all reasonable ways to assure the balanced wildlife habitat and to allow camping with the approval of the district superintendent and in areas subject to his approval. Except as otherwise specifically authorized herein, no act or practice shall be undertaken which will adversely affect the balance of nature in the district. The commission shall

make and promulgate such rules and regulations regarding the uses authorized herein as are reasonably necessary to conserve the wilderness, watershed and reservoir character of the district.

SECTION 3. No lands or real property which are a part of the district shall be leased or sold or otherwise transferred without approval of the general court, nor shall there be any new or additional construction on said lands or real property except by the commission consistent with the purposes of this act.

SECTION 4. No new or additional roads or ways shall be constructed within the district, excepting only such ways as shall be required for forest management and fire control, or for watershed and reservoir purposes, nor shall existing soft surface roads or ways be hard surfaced, provided, however, that existing ways may be maintained and kept passable and in repair.

SECTION 5. The commission shall not permit the dumping of refuse or waste within the district except where such is allowed by permit granted by the commission prior to the effective date of this act for as long as such permit remains in effect, except, however, the commission may dispose of such refuse or waste resulting from normal operation of the district.

SECTION 6. No person shall take or remove and no town within the district shall authorize the taking or removal of sand, gravel, dirt or soil, nor any other mineral, from or within the district, except only that the commission may take such of these materials as are required for commission use within the district and may allow such use of these materials as may be required pursuant to section five.

SECTION 7. The commissioner, or his designee, shall annually prepare a plan detailing forestry activities, logging or lumbering activities, proposed plantings and the like which are to be undertaken for the next following year, which plan shall be open to inspection by the public.

SECTION 8. Lumbering or logging operations shall be permitted within the district to the extent and for the purpose of maintaining and conserving its forests in a healthful state of natural ecological balance consistent with reservoir and watershed purposes, but such lumbering and logging operations shall not be of a tree farming nature, so called, wherein natural diversification of tree species is upset nor wherein wildlife habitat or food chain growth is adversely affected. All lumbering or logging operations shall be performed under private contract pursuant to the bidding laws of the commonwealth the proceeds of which shall be used in whole or in part for the further management of the selfsame forests, excepting only for such emergency salvage operations as are deemed necessary by the forester, and with the further exception that the commission may take such lumber as is needed for its own use consistent with this act. All such lumber or logging operation s shall be supervised by the forester who shall designate cuttings and shall make and enforce such rules as are necessary regarding disposal of slash and toppings, construction of logging ways or ramps, or the like, to conserve said forests within the intent of this act. No tree shall be felled or cut within one hundred feet of any river or stream or flow line of reservoir or pond with the district which change the character of stream beds, except for such emergency or salvage cuttings as aforesaid.

SECTION 9. The public shall have access to the lands of the district for such recreational uses as are permitted by, and are consistent with the provisions of this act, except that the Prescott peninsula shall be set aside as a natural site for ecological and wildlife study and access thereto shall be regulated by the commission.

SECTION 10. Hunting shall not be allowed in the Quabbin reservoir area [NOTE: amended by Chapter 436 of the Acts of 1990 to allow hunting in accordance with a deer management program.], however hunting may be permitted within the Ware river watershed subject to the rules and regulations of the commission and the division of fisheries and game regulating hunting.

SECTION 11. Powered boats or powered canoes shall not be used anywhere within that portion of the Ware river lying within the present bounds of Routes 68, 62, 122, 122A and 56, nor shall all-terrain or amphibious vehicles be operated in, on or through the streams, ponds or other waters within these same bounds except for official use.

SECTION 12. There shall be no overnight camping within the Quabbin reservoir area nor within that portion of the Ware River Watershed defined in the first sentence of section eleven of this act, nor shall tents be erected nor trailers or vehicular sleeping accommodations be parked overnight therein.

SECTION 13. Motor vehicles, snowmobiles and other recreation al vehicles may be operated within the Ware River Watershed only upon established vehicular ways and trails, or in such other areas as shall be designated by the commission. Public entry to the Quabbin reservoir area shall be limited to foot passage only, except that motor vehicles and manually operated bicycles may be admitted to such roads and ways within the Quabbin reservoir area as shall be designated by the commission. There shall be no racing of motor driven vehicles within the district, nor shall any associated rallies or commercial ventures be held therein. Snow vehicles or all-terrain vehicles shall be permitted within the Quabbin reservoir area only for official use.

SECTION 14. Notwithstanding any other provision of this act the establishment, construction and operation by the University of Massachusetts, hereinafter referred to as the university, of an astronomical observatory may be continued in compliance with and pursuant to the permit granted November twenty-sixth, nineteen hundred and sixty-nine by the commission, to the university, provided that access to the site of the said astronomical observatory shall be limited to such access road as may be specifically designated by the commission for the purpose, and provided further that no person or equipment, other than construction, maintenance and repair personnel and equipment, operating personnel and equipment and such students in the field of astronomy as may be authorized by the university for the purpose, shall be entitled to be admitted to the aforesaid site except in accordance with and under the provisions of this act. Any such person so admitted shall be subject to supervision while on the site by an officer or official of the university designated for said purpose. Similarly, the construction, maintenance and operation of the United States Air Force antenna installations in compliance with and pursuant to the permit granted November twenty-sixth, nineteen hundred and sixty-nine may be continued under the agreements pertaining thereto.

SECTION 15. The provisions of this act and of all rules and regulations made under the authority thereof shall be enforced by the commissioner, his duly appointed agents, by metropolitan district commission police officers, by police officers of any city or town, by members of the state police and by enforcement officers of the department of natural resources.

10.2.2 350 CMR 11.00 Watershed Protection Regulations

Official Disclaimer: These regulations are provided to you for your convenience. Official versions of all Massachusetts State statutes are available through the State Bookstore. When downloading from the web please be aware that the copy you receive may differ from the official version. If you need the statutes for work that may have any legal implications, make sure to get the official version from the State bookstore.

Department of Conservation and Recreation; with corrections, May, 1994

Section

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11.01 Introduction and Purpose

(1) Introduction - 350 CMR 11.00 is promulgated by the Commissioners of the Department of Conservation and Recreation pursuant to the authority granted under St. 1992 c. 36. St. 1992 c. 36, ə 2 amends M.G.L. c. 92, ə 104 by adding certain definitions which are used in 350 CMR 11.03; St. 1992 c. 36, ə 3 adds M.G.L. c. 92, ə 107A defining the jurisdiction and exemptions contained in 350 CMR 11.04 and 350 CMR 11.05, respectively; and St. 1992 c. 36, ə 4 amends M.G.L. c. 92, ə 108 by requiring the Division of Watershed Management, after consultation with the Department of Environmental Protection, to make rules and regulations for the protection of Watersheds as defined in St. 1992 c. 36.

In addition, St. 1992 c. 36 and M.G.L. c. 92 authorize the Department of Conservation and Recreation and the Division of Watershed Management to make rules and regulations to protect the Watersheds as

defined in St. 1992 c. 36 and the Watershed System as defined in St. 1992 c. 36 and M.G.L. c. 92. The Department of Environmental Protection is also required under St. 1992 c. 36, ɜ 14 to adopt rules and regulations for the prevention of pollution and securing the sanitary protection of all waters used as sources of water supply in the Commonwealth other than in the Watersheds as defined in St. 1992 c. 36. Regulations currently exist for:

(a) the sanitary protection of waters used by the Department of Conservation and Recreation (310 CMR 23.00);

(b) land within Watershed Reservations (350 CMR 8.00);

(c) sanitary rules and regulations for the Metropolitan Water Supply (350 CMR 9.00); and

(d) fishing in Wachusett and Sudbury Reservoirs (350 CMR 10.00).

In order to facilitate review of all regulations promulgated by the Department of Conservation and Recreation and the Division of Watershed Management relating to Watersheds and the Watershed System, 350 CMR 11.09 includes regulations of general applicability to Waters of the Watershed System. The regulations in 350 CMR 11.09 are intended to supersede the regulations in 310 CMR 23.00, 350 CMR 8.01, 350 CMR 9.00, and 350 CMR 10.00, which shall be repealed on March 31, 1994.

(2) Purpose - The purpose of St. 1992 c. 36 is to improve the protection of the metropolitan water supply. St. 1992 c. 36 and 350 CMR 11.00 set forth a comprehensive scheme to regulate land use and activities within certain critical areas of the Watersheds and Watershed System.

The purpose of 350 CMR 11.00 is to define and clarify the restrictions and prohibitions set forth in St. 1992 c. 36 by establishing standard definitions and procedures under which the Division of Watershed Management may carry out its responsibilities under St. 1992 c. 36. 350 CMR 11.00 shall complement St. 1992 c. 36 and shall have the force of law on March 31, 1994.

11.02: General Provisions

(1) Time Periods. Unless otherwise specifically provided in St. 1992 c. 36 or 350 CMR 11.00, computation of any time period referred to in 350 CMR 11.00 shall begin with the first day following the action which initiates the running of the time period. The last day of the time period so computed is to be included unless it is a Saturday, Sunday or legal holiday or any other day on which the office of the Division is closed, in which event the period shall run until the end of the next following business day. When the time period is less than seven days, intervening days when the Division is closed shall be excluded in the computation.

(2) Timely Filing. All Papers must be filed at the Division office or such other place as the Division shall specify in 350 CMR 11.00 within the time limits set forth herein.

Unless otherwise specifically provided in St. 1992 c. 36 or 350 CMR 11.00, Papers filed in the following manner shall be deemed to be filed as set forth herein:

(a) *Hand delivery during business hours*. By hand delivery during business hours shall be deemed filed on the day delivered.

(b) *Hand delivery during non-business hours*. By hand delivery at times other than during regular business hours shall be deemed filed on the next regular business day.

(c) *Mailing*. By placing in the United States Mail certified or registered mail, return receipt requested shall be deemed filed on the date received by the Division.

All Papers shall show the date received by the Division and the Division shall cooperate in giving date receipts to Persons filing Papers by hand delivery.

(3) Actions by the Division. Where St. 1992 c. 36 states that a particular action (except receipt of a request or notice) is to be taken by the Division, that action is to be taken by the person designated by 350 CMR 11.00 or, if by a committee, by more than half the members present at a meeting of at least a quorum. A quorum is defined as a Majority of the members then in office.

(4) Burden of Proof. Any Person who files a request for Advisory Ruling, a request for Watershed determination of applicability, an application for variance or a request for Exemption of a Tributary shall have the burden of producing credible evidence from a competent source in order to demonstrate to the Division or, in the case of an appeal, to the Commission, support for the position taken or the relief requested.

(5) Capitalized Terms. Any capitalized terms used in 350 CMR 11.00 shall have the meanings ascribed to such terms in 350 CMR 11.03.

11.03 Definitions

Advisory Ruling means a ruling issued by the Division pursuant to 350 CMR 11.06(1).

Agriculture, Land in Agricultural Use and Normal Maintenance or Improvement of Land in Agricultural Use shall have the meanings ascribed to such terms in 310 CMR 10.04.

Alteration means:

(a) draining, dumping, dredging, damming, discharging, excavating, filling or grading;

(b) the erection, reconstruction or substantial expansion of any buildings or Structures;

(c) the driving of pilings;

(d) the construction or reconstruction or paving of roads and other ways;

(e) the construction or reconstruction of utilities;

(f) the changing of run-off characteristics;

(g) the intercepting or diverting of ground waters, surface waters, reservoirs, tributaries, or aquifers; and

(h) the installation or substantial expansion of drainage, sewage and water systems.

Applicability Decision means the written decision issued by the Division pursuant to 350 CMR 11.06(2)(e).

Aquifer means a geological formation, group of formations, or part of a formation in the Wachusett Watershed that is capable of yielding a significant amount of water to a well or spring, as determined by reference to the Maps, 350 CMR 11.07. The land directly overlaying an aquifer shall be deemed to be part of said aquifer.

Authority means the Massachusetts Water Resources Authority.

Bank means the portion of the land surface which normally abuts and confines a water body. It occurs between a water body and a Bordering Vegetated Wetland and adjacent Flood plain, or in the absence of these, it occurs between a water body and an upland. A bank may be partially or totally vegetated or may be comprised of exposed soil, gravel or stone. The upper boundary of a bank is the first observable break in the slope or the mean annual flood level, whichever is lower. The lower boundary of a bank is the mean annual low flow level.

Bordering Vegetated Wetland means a wet meadow, except meadows used for the grazing of livestock, marsh, swamp, bog or other area, hydrologically connected to and bordering on a Tributary, Reservoir, Flood plain, or Surface Water, which supports at least 50% wetland species and as defined in the Wetlands Protection Act as defined herein.

Commission means the Department of Conservation and Recreation.

Commonwealth means the Commonwealth of Massachusetts.

Date of Issuance means the date a determination, order or decision is hand delivered or mailed as provided in 350 CMR 11.00.

Date of Submission means the date the Division assigns a file number to a request or application submitted pursuant to 350 CMR 11.06. Assignment of a file number shall not imply that a request, application or supporting documents have been determined adequate to support the relief requested, but only that the submission is complete in accordance with the requirements of 350 CMR 11.06.

Department means the Department of Environmental Protection of the Commonwealth of Massachusetts.

Discharge or Discharge of Pollutant means any addition of Pollutants or combination of Pollutants from any source including, but not limited to, discharges from surface runoff, which are collected or channelled by man and through pipes, sewers or other conveyances.

Disposal means the discharge, deposit, injection, dumping, spilling, leaking, incineration or placing into or on any land or water so that the matter disposed of may enter the environment or be emitted into the air or discharged into any waters, including Ground water.

Division means the Division of Watershed Management of the Commission.

Dwelling means any structure or building, or any portion thereof which is used, intended to be used, or designed to be occupied for human habitation purposes, including, but not limited to, houses, hotels, motels, apartments and condominiums.

Exemption Decision means a decision of the Division, in consultation with the Department, to exempt a Tributary from regulation under St. 1992 c. 36 issued pursuant to 350 CMR 11.06(4)(g).

Flood plain means the land adjoining a Tributary, Reservoir or Surface Water, which is subject to inundation from a flood having a 1% chance of being equaled or exceeded in any given year, commonly known as the 100 year flood plain, as determined by reference to the Maps, 350 CMR 11.07.

Generate or Generation of Pollutants means the origination, creation or production of Pollutants.

Ground water means water below the land surface in a saturated zone, including perched ground water.

Hazardous Material or Waste means any material or waste, in whatever form, which because of its quantity, concentration, corrosivity, flammability, reactivity, toxicity, or infectious, chemical or radioactive characteristics, either separately or in combination with any substance or substances, constitutes a present or potential threat to human health, safety, welfare, or to the environment. Hazardous Material or Waste shall include those materials listed in 40 CFR 261, or 310 CMR 40.900 Appendix I.

Impervious means not allowing entrance or passage of water due to the presence on or above the ground of material having a percolation rate of greater than 30 minutes per inch, including, but not limited to, pavement, concrete, stone, peat, loam and other organic matter.

Leaching Field means a soil absorption system as such term is defined in Title 5 (350 CMR 15.00).

List of Affected Parcels means the list developed by the Division from maps prepared pursuant to M.G.L. c. 92 э 107A(q).

Lot means an area of land subject to St. 1992 c. 36 in one ownership with definite boundaries described in a deed or shown on a plan recorded in the registry of deeds or registered in the registry district of the land court.

Maps means the maps described in 350 CMR 11.07.

Majority means more than half of the members of any body making a decision pursuant to 350 CMR 11.00.

Natural Basin means an area bounded peripherally by a water parting and draining ultimately to a particular water course or body of water; the catchment area or drainage basin from within which the waters of a stream or stream system are drawn.

Owning an Interest in Real Property or Real Property Interest means having alone, or jointly or severally with others:

(a) legal title to real property;

(b) the care, charge or control of real property in any capacity including, but not limited to as agent, executor, executrix, administrator, administratrix, trustee, or guardian of the estate of the holder of legal title;

(c) lessee under a written lease; or

(d) an agent, trustee or other person appointed by the Courts of the Commonwealth.

Papers means all requests, documents, papers, notices, appeals and other written communications permitted or required by the regulations to be filed with the Division or the Commission.

Party Aggrieved means any Person who, because of an act or failure to act by the Division or the Commission under St. 1992 c. 36 or 350 CMR 11.00, may suffer an injury in fact which is different, either in kind or magnitude, from that suffered by the general public, and which is within the scope of the interests identified in St. 1992 c. 36. Such party must specify, in writing, sufficient facts to allow the Division or the Commission to determine whether or not the party is, in fact, aggrieved.

Person means an individual, partnership, corporation, firm, association or group, including a city, town, county, the Commonwealth or other governmental unit owning property or carrying on an activity regulated by St. 1992 c. 36.

Plans means such data, maps, engineering drawings, calculations, specifications, schedules and other materials, if any, deemed necessary by the Division to describe the Lot, portion of the Lot or the Alteration to determine the applicability of St. 1992 c. 36 or to determine the impact of the Alteration upon the interests identified in St. 1992 c. 36.

Pollutant means any substance, man-made or resulting from human activities, that can alter the biological, chemical, physical, or radiological character of water.

Reservoir means either the Wachusett or the Quabbin Reservoir.

Sewage Treatment Facility means any wastewater treatment facility used for treating, neutralizing or stabilizing sewage, including: treatment or disposal plants; the necessary intercepting outfall and outlet sewers; pumping stations integral to such facilities; and equipment and appurtenances related to the foregoing.

Sewer System means pipelines or conduits, pumping stations, force mains, and all other structures, devices, appurtenances, and facilities used for collecting and conveying wastes to a site or works for treatment or disposal.

Storage means the actual or intended containment on a temporary basis or permanent basis which does not constitute Disposal.

Structure means a combination of materials assembled at a fixed location to give support or shelter, such as, but not limited to, a Dwelling, a building, framework, retaining wall, tent, reviewing stand, platform, bin, fence over six feet high, sign, flagpole, recreational tramway, mast for radio antenna or the like. The word “structure” shall be construed, where the context requires, as though followed by the words “or part or parts thereof.”

Subsurface Waste Water Disposal System means an on-site subsurface sewage disposal system as defined in Title 5 (310 CMR 15.00).

Surface Water(s) means water in the Watersheds, including any lake, spring, impoundment, and pond, as determined by reference to the Maps, 350 CMR 11.07. Surface water shall include the land located thereunder and the Banks thereto. Surface water shall exclude all Reservoirs, Tributaries, Aquifers, Ground waters, and man-made farm ponds used for irrigation, as well as so-called great ponds of the Commonwealth which do not drain into a Tributary or a Reservoir.

Title 5 means Title 5 of the Massachusetts Environmental Code governing standard requirements for the siting, constructing, repair, replacement and maintenance of on-site sewage treatment and disposal systems, 310 CMR 15.00.

Treatment means any method, technique, or process, including neutralization, incineration, stabilization or solidification, designed to change the physical, chemical or biological character or composition of any Hazardous Material or Waste so as to neutralize such Material or Waste or so as to render such Material or Waste less hazardous, non-hazardous, safer to transport, amenable to storage, or reduced in volume, except such method or technique as may be included as an integral part of a manufacturing process at the point of generation.

Tributary means a body of running water, including a river, stream, brook and creek, which moves in a definite channel in the ground due to a hydraulic gradient and which flows ultimately into a Reservoir in the Watersheds or the Ware River above the Ware River intake, as determined by reference to the Maps, 350 CMR 11.07. A Tributary shall include the land over which the water therein runs and the Banks thereto.

Uses and Activities means those uses and activities described in M.G.L. c. 92, ϶ 107A(a) and (b)(2) and 350 CMR 11.04(3).

Variance Decision means the written decision issued by the Division pursuant to 350 CMR 11.06(3)(g).

Waters of the Watershed System means all waters that in their natural course would flow into the Ware River above the Colbrook Diversion, the open channel of the Wachusett Aqueduct, the Quabbin, Wachusett, Sudbury and Foss reservoirs and any other lake, pond, reservoir, aqueduct, stream, ditch, watercourse or any other open water under the provision of M.G.L. c. 92, ϶ 109.

Watershed Reservation(s) means land within the Watershed System and described in St. 1972 c. 737 as amended by St. 1990 c. 436.

Watershed(s) means the Natural Basin from within which water drains or in the natural course would drain into the Quabbin Reservoir, the Wachusett Reservoir, or the Ware River upstream of the Ware River intake.

Watershed System means:

(a) all real and personal property interests held by or on behalf of the Commonwealth immediately prior to the effective date of St. 1992 c. 36 in and for the Department of Conservation and Recreation water system which were part of or appurtenant to the Quabbin Watershed, Quabbin Reservoir, Ware River Watershed, Wachusett Watershed, Wachusett Reservoir, North and South Sudbury watersheds, Sudbury Reservoir, Framingham Reservoirs 1, 2 and 3, Blue Hills Reservoir, Bear Hill Reservoir, Spot Pond Reservoir, Fells Reservoir, Weston Reservoir, Norumbega Reservoir, Chestnut Hill Reservoir, including land, easements, buildings, Structures, all equipment, machinery, vehicles and appliances, improvements, water rights and rights in source of water supply; and

(b) all enlargements and additions to the former Department of Conservation and Recreation water system acquired or constructed by the Division for the purpose of the Watershed System, including land, easements, buildings, Structures, equipment, machinery, vehicles, and appliances, improvements, reservoirs, dams, water rights and rights in sources of water supply, but excluding the Waterworks System of the Authority.

Waterworks System means waterworks system as defined in M.G.L. c. 92 App. and 360 CMR 10.00 et seq..

Wetlands Protection Act means the Wetlands Protection Act, M.G.L. c. 131, ϶ 40 and regulations promulgated pursuant thereto, 310 CMR 10.00 et seq.

11.04: Jurisdiction

(1) *Areas Regulated*. Areas regulated by St. 1992 c. 36 and 350 CMR 11.00 include those portions of the Watersheds which lie:

(a) within 400 feet of the Bank of a Reservoir;

(b) within 200 feet of the Bank of a Tributary or Surface Waters;

(c) within the area between 200 and 400 feet of the Bank of a Tributary or Surface Waters;

(d) within the Flood plain of a Tributary or Surface Waters, including that flood plain;

(e) within Bordering Vegetated Wetlands that border on Tributaries or Surface Waters or Reservoirs;

(f) within land that overlays an Aquifer with a potential well yield of 100 gallons per minute or more as determined in accordance with St. 1992 c. 36 and 350 CMR 11.00; or

(g) within land that overlays an Aquifer with a potential well yield of one or more but less than 100 gallons per minute pursuant to a finding by the Division, in consultation with the Department, that regulation of said Aquifer is necessary for the protection of the quality of the water in the Surface Waters, Aquifers, Reservoirs or Tributaries.

(2) *Presumptions - Properties Identified in the List of Affected Parcels*. For purposes of 350 CMR 11.00, all properties identified in the List of Affected Parcels shall be presumed to be in an area regulated under 350 CMR 11.04(1)(a) through (g). Any property which is not identified in the List of Affected Parcels shall be presumed not to be in an area regulated under 350 CMR 11.04(1)(a) through (f).

(3) *Uses and Activities Regulated or Prohibited*.

(a) Any Alteration, or the Generation, Storage, Disposal or Discharge of Pollutants is prohibited within those portions of the Watershed that lie:

1. within 400 feet of the Bank of a Reservoir (350 CMR 11.04(1)(a)); or

2. within 200 feet of the Bank of a Tributary or Surface Waters (350 CMR 11.04(1)(b)).

(b) 1. Within those portions of the Watershed that lie:

a. within the area between 200 and 400 feet of the Bank of a Tributary or Surface Water (350 CMR 11.04(1)(c));

b. within the Flood plain of a Tributary or Surface Water (350 CMR 11.04(1)(d));

c. within Bordering Vegetated Wetlands that border on Tributaries or Surface Waters or Reservoirs (350 CMR 11.04(1)(e));

d. within land that overlays an Aquifer with a potential well yield of 100 gallons per minute or more as determined in accordance with St. 1992 c. 36 and 350 CMR 11.00 (350 CMR 11.04(1)(f)); or

e. within land that overlays an Aquifer with a potential well yield of one or more but less than 100 gallons per minute, pursuant to a finding by the Division, in consultation with the Department, that regulation of said Aquifer is necessary for the protection of the quality of the water in the Surface Waters, Aquifers, Reservoirs or Tributaries (350 CMR 11.04(1)(g)),

2. The following uses are prohibited:

a. the Disposal of Pollutants from either privately or publicly owned Sewage Treatment Facilities;

b. the placement of the Leaching Field of a Subsurface Waste Water Disposal System less than four feet above the maximum water table level as measured at the time of annual high water;

c. the storage of liquid petroleum products of any kind; provided, however, that an end user of such product, such as a resident in connection with normal residential use or a person responsible for supplying heat to a residence, may store a reasonable volume of such material so long as such storage is in a free standing container inside of the Structure, which Structure shall include at a minimum a foundation thereof with a poured cement slab floor or a concrete reservoir of sufficient volume to hold 125 percent of the tank's capacity;

d. the Treatment, Disposal, use, generation or Storage of Hazardous Material or Waste, except a reasonable volume of Hazardous Material or Waste incidental to normal residential use;

e. the Storage and the Disposal of solid waste other than a reasonable volume incidental to normal residential use;

f. the outdoor Storage of road salt or other de-icing chemicals; provided, however, that 350 CMR 11.00 shall not prohibit the outdoor Storage of sand, gravel or materials used in road construction which are not Hazardous Materials or Waste;

g. the outdoor Storage of fertilizers, herbicides and pesticides;

h. the use or Storage of pesticides or herbicides which carry a mobility rating as provided for by the United States Environmental Protection Agency or which have been determined by the Commonwealth using United States Environmental Protection Agency standards to pose a threat or potential threat to Ground water;

I. the outdoor, uncovered Storage of manure;

j. the servicing, washing or repairing of boats or motor vehicles other than as reasonably incidental to normal residential use;

k. the operation of junk and salvage yards;

l. the rendering Impervious of more than ten percent of any Lot or 2,500 square feet, whichever is greater;

m. the excavation of gravel and sand to a depth greater than six feet above the maximum water table, except where incidental to the construction of permitted Structures;

n. the Alteration of Bordering Vegetated Wetlands;

o. any other activity which could degrade the quality of the water in the Watersheds as determined by the Division after consultation with the Department; provided, however, that de-icing may be performed on a roadway under procedures approved by the Commonwealth's Secretary of Environmental Affairs; or

p. the construction of any Dwelling which exceeds a density of two bedrooms per acre or any use which may generate more than 220 gallons of sanitary sewage per acre per day.

(c) In addition to, and without limiting, the prohibitions contained in 350 CMR 11.04(3)(a) and (3)(b), within those portions of the Watersheds which overlay Aquifers with potential well yields of between 100 and 300 gallons per minute as determined by the Division, or land whose regulation has been determined to be necessary for the protection of the quality of the water in the Surface Waters, Aquifers, Reservoirs and Tributaries, pursuant to 350 CMR 11.04(1)(g), the construction of any Dwelling which exceeds a density of one and one-third bedrooms per acre and any use which may generate more than 147 gallons of sanitary sewage per acre per day are prohibited.

(d) In addition to, and without limiting, the prohibitions contained in 350 CMR 11.04(3)(a), (3)(b) and (3)(c), within those portions of the Watersheds that overlay Aquifers with potential well yields of over 300 gallons per minute as determined by the Division, the construction of any Dwelling which exceeds a density of one bedroom per acre and any use which may generate more than 110 gallons of sanitary sewage per acre per day are prohibited.

(e) In making the calculation required under 350 CMR 11.04(3)(b)2.l. all contiguous real property within an area described in 350 CMR 11.04(1) owned by the same Person shall be used, in the aggregate; provided, however, that said area may be so used in making such calculation for only one Lot.

(f) In making the calculation required under 350 CMR 11.04(3)(b)2.p., all contiguous real property within an area described in 350 CMR 11.04(1) owned by the same Person shall be used, in the aggregate, to determine the total acreage for density purposes; provided, however, that said area may be so used for determining area density for only one Lot.

11.05: Exemptions

The provisions of 350 CMR 11.04 shall not apply to the following:

(1) *Uses, Structures or Facilities in Existence*. Uses, Structures or facilities lawfully in existence or for which all applicable municipal, state and federal permits and approvals, other than building permits and permits for septic systems, were obtained prior to July 1, 1992;

(2) *Reconstruction, Extension or Structural Change*. Any reconstruction, extension or structural change to any Structure lawfully in existence on July 1, 1992, provided that such reconstruction, extension or structural change:

(a) does not constitute a substantial change to or enlargement of that lawfully existing Structure; and

(b) does not degrade the quality of the water in the Watershed;

(3) *Lot in Existence*. The construction of one single-family Dwelling on any Lot existing as such prior to July 1, 1992, or the division of an owner occupied Lot existing as such as of July 1, 1992 into one additional Lot for a single family dwelling; provided that, wherever possible, there shall be no Alterations within the areas described in 350 CMR 11.04(1)(a) and 11.04(1)(b);

(4) *Construction - Sewer System*. The construction of any Dwelling described in 350 CMR 11.04(3)(b)2.p., 11.04(3)(c) or 11.04(3)(d) if a Sewer System existed prior to July 1, 1992 to which a direct connection shall be made without expansion of capacity and said connection is used for all sanitary sewage of any Dwelling or other Structure resulting from said construction;

(5) *Tributaries*. Tributaries, or portions thereof, which the Division, in consultation with the Department, has exempted pursuant to 350 CMR 11.00, upon a determination that such exemption will pose no

significant risk to the quality of the water, after taking into account the rate of flow, slope, soil characteristics, proximity to a Reservoir or the Ware River above the Ware River intake, the current level of water quality and the current degree of development;

(6) *Work of the Division*. The Division, in the performance of its responsibilities and duties to protect the quality of the water in the Watersheds, or the Authority in the performance of its responsibilities and duties to maintain, operate and improve the Waterworks System;

(7) *Conversion of Land for Agricultural Use*. Conversion of Land for Agricultural Use or preparation of Land for Agricultural Use; provided, however, that such conversion shall be made under a plan approved by the United States Department of Agriculture, Soil Conservation Service and the Commission, in consultation with the Commonwealth's Department of Food and Agriculture;

(8) *Maintenance of Public Roadways in Existence*. The maintenance, repair, replacement or reconstruction of public roadways existing as of September 1, 1989 or railroad track and rail bed existing as of September 1, 1990, including associated drainage systems, that are necessary to preserve or restore the facility's serviceability for the number of travel lanes and uses existing as of September 1, 1990; provided, however, that in the case of any replacement the design is substantially the functional equivalent of, and is of similar alignments to that which is being replaced; provided, further, that design plans and specifications for said work on roadways, or railroad track and rail beds are provided to the Division prior to the work's commencement;

(9) *Maintenance or Improvement - Agricultural*. Activities relating to normal maintenance or improvement of Land in Agricultural Use; provided, however, that such activities do not impair the quality of the water;

(10) *Construction of Public Highways*. The construction of public highways, railroad track and rail beds and facilities directly related to their operation; provided, that the Commonwealth's Secretary of Environmental Affairs has determined that such highway or transportation service construction project requires direct access to or location in the lands described in 350 CMR 11.04(1) to avoid or minimize damages to the environment and that said Secretary and the Division have determined that such construction does not materially impair the quality of the water in the Watersheds;

(11) *Maintenance of Public Utilities*. The maintenance, repair or expansion of lawfully located Structures or facilities used in the service of the public to provide electric, gas, water, sewer, telephone, telegraph and other telecommunication services; provided, however, that such maintenance, repair or expansion activities, Structures, or facilities do not materially impair the quality of water in the Watersheds as determined by the Division after consultation with the Department;

(12) *Maintenance of Public Utilities - Wetlands*. The maintenance, repair or replacement, but not the substantial changing or enlargement of, an existing and lawfully located Structure or facility used in the service of the public and used to provide electric, gas, water, sewer, telephone, telegraph and other telecommunication services in Bordering Vegetated Wetlands; provided, however, that such maintenance and repair activities do not materially impair the quality of water in the Watersheds;

(13) *Clean up or Prevention of Releases*. The undertaking by any Person, municipality, the United States government or the Commonwealth of temporary operations to clean up, prevent or mitigate releases of Hazardous Material or Waste;

(14) *Changes in Agricultural Crops Produced*. Changes in agricultural crops produced;

(15) *Agricultural Technologies*. The use of new or existing agricultural technologies that do not degrade the quality of water in the Watersheds more than the present agricultural technologies that such new or existing agricultural technologies replace; and

(16) *Municipal Sewage Treatment Facility or Water System*. The construction of a new municipal Sewage Treatment Facility or new municipal water system if the Division determines that water quality will not be adversely impacted from said construction and provided that such new systems comply with all existing regulations and standards applicable to water pollution abatement districts.

11.06: Procedures

(1) Advisory Rulings

(a) *Request for Advisory Ruling*. Any person Owning an Interest in Real Property may, by written request to the Division at the addresses specified in 350 CMR 11.11 by certified mail or hand delivery, request an Advisory Ruling as to:

1. whether such Person's property is located within an area regulated by St. 1992 c. 36 or 350 CMR 11.00; or

2. whether existing or proposed Structures, Uses or Activities on such Person's property are permitted under St. 1992 c. 36 or 350 CMR 11.00 by virtue of the exemptions set forth in 350 CMR 11.05.

(b) *Information Required*. Such written request shall identify the property by street address and include:

1. a copy of the current Assessor's Map showing the location of the property or reference to the applicable Assessor's Map by sheet and parcel number;

2. a copy of (or reference to) the most recent edition of the Massachusetts Geographic Information System map based on the United States Geological Survey, 1 to 25,000 scale, quadrangle maps, showing the location of the property;

3. a copy of such Owner's deed as recorded in the applicable registry of deeds; and

4. copies of any plans, mortgage inspection plans and tape surveys of the property which are available.

(c) *Issuance of Advisory Ruling*. Within 30 days of the Date of Submission of a request for Advisory Ruling, the Division may issue a written ruling to the Person who submitted the request, or in its sole discretion, the Division may notify such Person that a request for Watershed determination of applicability is required pursuant to 350 CMR 11.06(2).

(d) *Remedy*. The Person to whom an Advisory Ruling is issued shall have no right to appeal such ruling, but may at such Person's election, submit a request for Watershed determination of applicability or an application for variance in accordance with 350 CMR 11.00. A Person who has not been issued an Advisory Ruling within 30 days may, at such Person's election, resubmit the request, or submit a request for Watershed Determination of Applicability or an application for variance in accordance with 350 CMR 11.06.

(e) *Authorization; limitations*. Any Advisory Ruling hereunder shall be issued by the Division pursuant to and subject to the limitations of M.G.L. c. 30A, ϶ 8.

(2) Requests for Watershed Determinations of Applicability

(a) *Filing*. Any Person Owning an Interest in Real Property who desires a determination as to whether or not:

1. such Person's property is located within an area regulated by St. 1992 c. 36 or 350 CMR 11.00;

2. proposed Structures, Uses or Activities on such Person's property are permitted under St. 1992 c. 36 or 350 CMR 11.00;

3. a reconstruction, extension or structural change constitutes a substantial change or enlargement or one which will degrade the quality of water under 350 CMR 11.05(2);

4. Alterations within areas described in 350 CMR 11.04(1)(a) and 11.04(1)(b) in connection with construction permitted under 350 CMR 11.05(3) are possible;

5. the maintenance, repair or replacement activities described in 350 CMR 11.05(9), (10) or (11) will impair or materially impair the quality of the water in the Watersheds; or

6. a new municipal Sewage Treatment Facility or new municipal water system will have an adverse impact on water quality under 350 CMR 11.05(16),

may submit to the superintendent of the Reservoir of the Watershed in which such property is located at the address specified in 350 CMR 11.11, by certified mail or hand delivery, a request for Watershed determination of applicability (See 350 CMR 11.13).

(b) *Land Surveyor Determination*. Any request for Determination under 350 CMR 11.06(2)(a)1. shall be accompanied by a written determination of a land surveyor registered with the board of registration of professional engineers and land surveyors of the Commonwealth as to whether such Person's real property interests are located within areas regulated by St. 1992 c. 36.

(c) *Related Statement*. Requests for Watershed Determinations other than those in 350 CMR 11.06(2)(a)1. shall include a detailed description of the Structures, Uses and Activities which are proposed.

(d) *Additional Materials*. All surveys and additional materials or studies required to make a determination, whether or not requested by the Division, shall be prepared and delivered at the sole cost of the Person desiring the determination.

(e) *Issuance of Applicability Decision*. Within 60 days of the Date of Submission of such request for Watershed Determination, the Division shall issue a written Applicability Decision to the Person who submitted such request, in form suitable for recording in the registry of deeds or registration in the registry district of the land court where the property is located (See 350 CMR 11.13), which shall contain a brief statement of the reasons for the Decision. If the Division fails to issue the Applicability Decision within such 60 day period, the Division shall be deemed to have:

1. concurred with the land surveyor's determination set forth in a request for Determination under 350 CMR 11.06(2)(a)1.; or

2. determined that the proposed Structures, Uses and Activities on such Person's property described in the request for Determination are permitted by St. 1992 c. 36 and 350 CMR 11.00; or

3. determined that such Structures, Uses and Activities will not impair or materially impair the quality of water in the Watersheds.

(f) *Appeal*. A Person to whom the Division's Applicability Decision has been issued, who seeks to appeal such Decision, shall file a Notice of Claim for an Adjudicatory Proceeding with the Commission at the address specified in 350 CMR 11.11 within 21 days from the Date of Issuance of the Decision by the Division. The procedures for appeal before the Commission shall be as set forth in 801 CMR 1.00 et seq. At the time of filing of such Notice of Claim, a copy shall also be filed with the Division.

(3) Variances

(a) *Variances*. The Division may grant a variance from the provisions of St. 1992 c. 36 and 350 CMR 11.00 with respect to particular Structures, Uses and Activities, and shall grant, upon request, a variance with respect to crossings of Tributaries and Bordering Vegetated Wetlands, where the Division specifically finds that owing to circumstances relating to the soil conditions, slope, or topography of the land affected by such Structures, Uses or Activities, desirable relief may be granted without substantial detriment to the public good and without impairing the quality of water in the Watersheds.

(b) *Presumptions and Standards for Required Findings*.

1. There shall be a presumption that granting a variance from the applicability of St. 1992 c. 36 and 350 CMR 11.00 to specific Structures, Uses and Activities is contrary to the achievement of the purpose of St. 1992 c. 36. This presumption may be rebutted only by the submission of credible evidence by the Person submitting the application for variance to establish that such variance may be granted without substantial detriment to the public good and without impairment of water quality in the Watersheds.

2. The standard of substantial detriment to the public good shall mean a factual determination by the Division of the overall effect of the proposed Structure, Use or Activity at a particular location in relation to the purpose of St. 1992 c. 36.

3. The standard of impairment of water quality shall mean:

a. the risk of water quality impairment presented by Structures, Uses and Activities which are permissible under all other relevant federal, state and local laws, but would not be permissible under 350 CMR 11.00 without a variance; and

b. the cumulative risk of water quality impairment from all Structures, Uses and Activities allowed under current regulations over time.

(c) *Applications.* Any Person Owning an Interest in Real Property may make an application for variance to the Division (See 350 CMR 11.13) by filing the same by certified mail or hand delivery with the Division at the address specified in 350 CMR 11.11. A copy of the application for Variance shall be sent to the Department at the address specified in 350 CMR 11.11.

(d) *Detailed Statement.* The application for variance shall include a detailed description of the Structures, Uses and Activities proposed on such Person's property. The application for variance shall include detailed information regarding each specifically enumerated factor stated in 350 CMR 11.06(3)(a). Detailed information regarding each factor shall be provided as follows:

1. *Soil Conditions*. A map prepared at a minimum scale of 1”=100’ indicating the soil types as mapped by the USDA Soil Conservation Service (“SCS”) shall be provided. Site specific soils data, including borings, test pits and percolation tests, may be submitted including copies of all field logs, notes, observations, conclusions and test methods employed. A detailed analysis of the soil characteristics of erodibility and permeability shall be provided. Permeability should be described in terms of percolation rate measured as minutes per inch as specified in Title 5 (310 CMR 15.00).

2. *Slope*. Calculations of the ground slope at all lands within the areas that would be subject to St. 1992 c. 36 if the variance were not granted shall be provided. The results of such calculations shall be presented graphically on a map prepared at a scale of 1”=100’ or larger, expressed as percent slope. Where applicable, the average slope of a Tributary measured as the change in elevation divided by the distance in stream miles from the upstream point of the Tributary at or near such Person’s property to the downstream point of the Tributary at or near such Person’s property shall also be stated.

3. *Topography*. A topographical plan at a minimum scale of 1”=100’ or larger showing contour elevations at two foot intervals shall be submitted. Said plan shall be prepared and stamped by a professional surveyor or engineer registered in the Commonwealth of Massachusetts and shall show the location of all areas which would be subject to St. 1992 c. 36 if the variance were not granted. The plan shall show the location of all Ground water, soil and percolation test locations. Such topographic information as depth to the maximum annual high Ground water table, depth to ledge or refusal, and distances from all mapped and unmapped streams, ponds and water bodies shall also be provided.

4. *Water Quality*. The application shall include a detailed analysis of the impacts on Surface Water and, where applicable, Ground water quality of any proposed Structure, Use or Activity which would be allowed if the variance is granted. An evaluation of the potential impact of such proposed Structure, Use or Activity on water quality by reference to the Department’s Surface Water Quality Standards for Class A Surface Waters and Outstanding Resource Waters of the Commonwealth, set forth in 314 CMR 4.00 et seq., and/or where applicable, the Massachusetts Ground Water Quality Standards, set forth in 314 CMR 6.00 et seq. shall be provided. The application shall include the water quality data and results to support each analysis and shall provide a detailed description of any methodology employed in performing such analysis to show that water quality will not be impaired by the Structure, Use and Activity for which the variance is being requested, whether during construction or upon continued use or operation of such Structure, Use or Activity.

5. *Mitigating Measures*. The application shall include an analysis of any mitigating measures which will be used which would enable the Division to grant a variance without substantial detriment to the public good and without impairing the quality of water in the Watersheds.

(e) *Additional Materials*. All surveys and additional materials or studies required to act on an application for variance, whether or not requested by the Division, shall be prepared and delivered at the sole cost of the Person submitting the application.

(f) *Public Hearing*. Within 30 days of the Date of Submission of the application for variance with the Division, the Division shall hold a public hearing. Notice of the time and place of the public hearing shall be given by the Division, at the expense of the Person who submitted the application, not less than five days prior to such hearing by publication in a newspaper of general circulation in the city or town where the property in question is located and by mailing a copy of such notice to the Person who submitted the application at the address specified in the application, and to the Building Inspector, Conservation Commission, and Board of Health in such

city or town. At the request of the Person who submitted the application filed with the Division at least two days before the date of such hearing, the date of the hearing may be rescheduled to a time which is mutually convenient for such Person and the Division, provided that such rescheduled time shall permit re-publication of notice as provided herein.

The public hearing may be continued, with the consent of the Person who submitted the application, to an agreed upon date, which shall be announced at the hearing. At the public hearing, such Person may be represented by counsel and/or professional consultants and may present oral or written evidence and oral or written testimony of witnesses.

(g) *Variance Decision*. Within 30 days of the close of the public hearing, the Division shall issue a written Variance Decision on the application for variance. If the variance is granted, the Division may impose in the Variance Decision such reasonable conditions, safeguards and limitations as it may find desirable in its sole discretion, which, based on the application for variance and the evidence presented at the public hearing, are necessary to protect the water in the Watersheds. If a variance is denied, the Variance Decision shall contain a brief statement of the reasons for the denial. The granting of a variance is limited to the provisions of St. 1992 c. 36. All other applicable laws, regulations and ordinances shall not be affected by the granting of a variance.

(h) *Recording of Variance Decision.* No variance granted hereunder shall take effect until a Variance Decision (See 350 CMR 11.13) shall have been recorded and indexed in the grantor index in the registry of deeds or registered in the registry district of the land court for the county or district where the property is located, containing any conditions applicable thereto and describing the land by metes and bounds or by reference to a recorded or registered plan showing the property's boundaries.

(i) *Appeal.* A Person to whom a Variance Decision is issued, who seeks to appeal the Division's Variance Decision, shall file a Notice of Claim for an Adjudicatory Proceeding with the Commission at the address specified in 350 CMR 11.11 within 21 days from the Date of Issuance of the Variance Decision by the Division. The procedures for appeal before the Commission shall be as set forth in 801 CMR 1.00 et seq. At the time of filing of such Notice of Claim, a copy shall also be filed with the Division.

(4) Exemption of a Tributary

(a) *Exemption of a Tributary*. The Division, in consultation with the Department, may exempt a Tributary, or portions thereof, upon a determination that such exemption will pose no significant risk to the quality of water, after taking into account the following factors:

1. rate of flow;

2. slope;

3. soil characteristics;

4. proximity to a Reservoir or the Ware River above the Ware River intake;

5. the current level of water quality; and

6. the current degree of development.

(b) *Presumptions and Standards for Required Findings*.

1. The standard of no significant risk to the quality of water refers to:

a. the risk of water quality impairment presented by Structures, Uses and Activities which are permissible under all other relevant state, federal and local laws, but would not be permissible under 350 CMR 11.00 without an exemption; and

b. the cumulative risk of water quality impairment from all Structures, Uses and Activities allowed under current regulations over time.

2. There shall be a presumption that exempting a Tributary or portion thereof is contrary to the achievement of the purpose of St. 1992 c. 36. The presumption may be rebutted only by the submission of credible evidence by the Person submitting the request for Exemption to establish that such exemption will pose no significant risk to the quality of water, taking into account the factors enumerated at 350 CMR 11.06(4)(a).

(c) *Requests for Exemption*.

1. A request for Exemption of a Tributary may be made by:

a. An affected landowner;

b. Any state agency or regional planning commission;

c. The Board of Selectmen, City Council, Mayor, Planning Board or Conservation Commission of any city or town which would be affected by the exemption; or

d. The Governor or any member of the General Court.

2. A request for Exemption of a Tributary shall be made to the Division (See 350 CMR 11.13) by filing the same by certified mail or hand delivery with the Division at the address specified in 350 CMR 11.11. A copy of the request for Exemption of a Tributary shall be sent to the Department at the address specified in 350 CMR 11.11.

(d) *Detailed Statement*. The request for Exemption of a Tributary shall include detailed information regarding each specifically enumerated factor listed in 350 CMR 11.06(4)(a)1. through 6. Such detailed information shall be provided based on conditions existing as of the time of the request and based on conditions which would, or may, result if such exemption were granted and if development occurred to the maximum extent and type allowed by current law. Detailed information on each factor shall be provided as follows:

1. *Flow Rate*. The request shall include the flow rate of the Tributary stated as the annual average daily stream flow, reported as cubic feet per second ("cfs") as measured at the downstream point of discharge for the Tributary or portion thereof, taking into account the entire contributing drainage area. Such flow rate may be based on field data collected in accordance with accepted stream flow measurement methods as established by the United States Geologic Survey, or estimated based on procedures established by the United States Geologic Survey. The request shall describe, in depth, the basis and method employed for the reported flow rate to assess full build-out scenarios.

2. *Slope*. The request shall state the average slope at the Tributary measured as the change in elevation divided by the distance in stream miles from its source to the downstream point of discharge. The ground slope of all lands adjacent to the Tributary

within the areas that would be subject to St. 1992 c. 36 if the exemption were not granted shall be calculated and the results of such calculations shall be presented graphically on a map prepared at a scale of 1”=100’ or larger, expressed as percent slope.

3. *Soil Characteristics*. A map prepared at a minimum scale of 1”=100’ shall be submitted indicating the soil types as mapped by the SCS. Site specific soils data supporting or contradicting the SCS soil mapping including borings, test pits and percolation tests may be submitted including copies of all field logs, notes, observations, conclusions and test methods employed. A detailed analysis of the soil characteristics of erodibility and permeability shall be provided. Permeability should be described in terms of a percolation rate measured as minutes per inch as specified in Title 5 (310 CMR 15.00).

4. *Proximity to a Reservoir or the Ware River above the Ware River Watershed*. Proximity of the Tributary proposed to be exempted to a Reservoir or the Ware River above the Ware River intake shall be indicated by reference to the Protection Zone, defined by the Department’s Division of Water Supply, Watershed Resource Protection Plan Policy as Zone A, Zone B and Zone C. The measured distance in stream miles from the downstream discharge point of the Tributary or portion thereof in question from that Tributary’s ultimate point of confluence with a Reservoir or stream miles above the Ware River intake shall be stated.

5. *Water Quality*. The request shall include water quality monitoring data for the Tributary consisting of, at a minimum monthly samples for a continuous one year period at a sampling station located at or near the downstream point of discharge of the Tributary or portion thereof for which exemption is requested. Water quality data of the Division and the Department may be utilized in satisfaction of this requirement where such data is available. Minimum analysis shall include fecal coliform bacteria, color, turbidity, temperature, pH, dissolved oxygen, total suspended solids, total phosphorus, ammonia nitrogen and chloride. A detailed analysis of the water quality data with reference to the Department’s Surface Water Quality Standards for Class A Surface Waters and Outstanding Resource Waters of the Commonwealth, 314 CMR 4.00 et seq., shall be provided. The request shall include a detailed analysis of the impact on water quality of any potential Structures, Uses or Activities allowed if the exemption is granted.

6. *Development*. A general plan showing existing land use within the contributing drainage area upstream at the point of discharge of the Tributary or portion thereof shall be provided. The request shall include a calculation of the percent imperviousness of the contributing drainage area based on the existing land uses shown and shall indicate the change of percent imperviousness which may result from any Structures, Uses or Activities allowed or proposed if the exemption is granted.

7. *Other Information*. The request shall include a detailed description of the Structures, Uses and Activities which are or may be proposed to occur within those areas which would be subject to St. 1992 c. 36 without the exemption and shall include an analysis of any mitigating measures which will be used which would ensure that granting the exemption would present no substantial risk to the quality of water.

(e) *Additional Materials*. All surveys and additional materials or studies required to act on a request for Exemption of a Tributary, whether or not requested by the Division, shall be prepared and delivered at the sole cost of the Person submitting the request.

(f) *Public Hearing*. Within 30 days of the Date of Submission of the request for Exemption of a Tributary with the Division and the Department, the Division and the Department shall hold a public hearing. Notice of the time and place of the public hearing shall be given by the Division, at

the expense of the Person who submitted the request, not less than five days prior to such hearing by publication in a newspaper of general circulation in the city or town where the property in question is located and by mailing a copy of such notice to the Person who submitted the request at the address specified in the request, and to the Building Inspector, Conservation Commission and Board of Health in such city or town. At the request of the Person who submitted the request filed with the Division at least two days before the date of such hearing, the date of the hearing may be rescheduled to a time which is mutually convenient for such Person, the Division and the Department, provided that such rescheduled time shall permit re-publication of notice as provided herein. The public hearing may be continued, with the consent of the Person who submitted the request, to an agreed upon date, which shall be announced at the hearing. At the public hearing, such Person may be represented by counsel and/or professional consultants and may present oral or written evidence and oral or written testimony of witnesses.

(g) *Exemption Decision*. Within 60 days of the close of the public hearing, the Division shall issue a written Exemption Decision on the request for Exemption of a Tributary. If the exemption is granted, the Division may impose in the Exemption Decision such reasonable conditions, safeguards and limitations as it may find desirable in its sole discretion, which, based on the request for Exemption of a Tributary and the evidence presented at the public hearing, are necessary to protect the water in the Watersheds. If the exemption is denied, the Exemption Decision shall contain a brief statement of the reasons for the denial. The granting of an exemption is limited to the applicability of St. 1992 c. 36. All other applicable laws, regulations and ordinances shall not be affected by the granting of an exemption.

(h) *Notice of Exemption.* Notice of the Exemption Decision shall be mailed to the Person who submitted the request, and to the City Council or Board of Selectmen in the city or town where the Tributary is located. Notice shall also be published once in a newspaper of general circulation in such city or town, provided, however, that a failure to publish shall not affect the validity of the Exemption Decision. A record of the Exemption Decision shall be kept on file with the Division and, if a Tributary or portion thereof is exempted, the affected area shall be shown on the most recent edition of the Massachusetts Geographic Information System Map (See 350 CMR 11.07).

(i) *Appeal.* A Person to whom an Exemption Decision is issued, who seeks to appeal the Division's Exemption Decision, shall file a Notice of Claim for an Adjudicatory Proceeding with the Commission at the address specified in 350 CMR 11.11 within 21 days from the Date of Issuance of the Exemption Decision by the Division. The procedures for appeal before the Commission shall be as set forth in 801 CMR 1.00 et seq. At the time of filing of such Notice of Claim, a copy shall also be filed with the Division.

(5) Work Pending Appeal of Applicability Decision, Variance Decision or Exemption Decision - No Alterations shall be made or Structures, Uses or Activities commenced until a final administrative or judicial determination has been made and all appeal periods shall have expired if the Division issues:

(a) an Applicability Decision that the property is located in an area regulated by St. 1992 c. 36, that the Structures, Uses or Activities proposed are prohibited by St. 1992 c. 36 under 350 CMR 11.04(3), or that the Structures, Uses or Activities will impair or materially impair the quality of water in the Watersheds; or

(b) a Variance Decision denying the variance requested in an application for variance; or

(c) an Exemption Decision denying a request for Exemption of a Tributary.

11.07: Maps

(1) *Aquifers*. The location and potential well yield of Aquifers shall be determined by reference to the most recent edition of maps generated by the Massachusetts Geographic Information System based on the United States Geological Survey Water Resource Atlases.

(2) *Flood plains*. The location of Flood plains shall be made by reference to the most recent edition of the Flood Hazard Boundary Maps issued by the Federal Emergency Management Agency.

(3) *Surface Waters and Tributaries*. The location of Surface Waters and Tributaries shall be determined by reference to the most recent edition of maps generated by the Massachusetts Geographic Information System based on the United States Geological Survey, 1 to 25,000 scale quadrangle maps.

(4) *Adoption of More Accurate Maps*. With respect to any of the maps referred to in 350 CMR 11.07, the Division, in consultation with the Department, may adopt more accurate maps pursuant to notice and a public hearing as provided by M.G.L. c. 30A. The Division shall file any of such maps which are adopted with the Clerk of the House of Representatives and Clerk of the Senate and such maps shall not take effect until 90 days have elapsed from the time of said filing. Copies of maps which have taken effect shall be filed with the Chief Executive Officers of all cities and towns within the Watersheds, provided that the Division's failure to do so shall not invalidate the maps or any actions taken by the Division in connection therewith.

11.08: Relationship of Act with other State and Municipal Statutes, Ordinances and Regulations

350 CMR 11.00 is intended solely for use in administering St. 1992 c. 36; nothing contained herein should be construed as preempting or precluding more stringent protection of the areas regulated by St. 1992 c. 36 by other statutes, ordinances, by-laws or regulations. The duties and obligations imposed by St. 1992 c. 36 shall be in addition to all other duties and obligations imposed by any general or special law or regulation or any by-law, ordinance or regulation lawfully adopted pursuant thereto.

11.09: General Rules and Regulations for the Protection of Watersheds and the Watershed System

In order to facilitate review of all regulations promulgated by the Commission and the Division relating to Watersheds and the Watershed System, this Section includes regulations of general applicability to Waters of the Watershed System. The regulations in 350 CMR 11.09 are intended to supersede the regulations in 310 CMR 23.00, 350 CMR 8.01, 350 CMR 9.00, and 350 CMR 10.00.

(1) *Waters of the Watershed System*

(a) No Person shall take or divert any Waters of the Watershed System of the Commission and no Person shall corrupt, render impure, waste or improperly use any such water.

(b) No Person shall:

1. engage in any construction activity involving filling, dredging, grubbing or altering land without adequate provisions to prevent erosion resulting in clay, silt or other turbidity laden waters from entering the Waters of the Watershed System;

2. construct, establish or maintain any agricultural facility or place where animal manure may be deposited or accumulated without adequate provision to prevent any manure or other Pollutant from flowing or being washed into the Waters of the Watershed System;

3. engage in any other activity which could degrade the quality of Waters of the Watershed System or interfere with their use as a source of water supply.

(c) No Person shall allow a condition to exist on such Person's property which could result in the direct or ultimate discharge of any Pollutant into the Waters of the Watershed System.

(d) Any records of any board of health or health agent concerning matters within the Watershed shall be open to inspection by the employees and agents of the Commission and the Department.

(e) Whenever an incident occurs, is likely to occur, or a situation exists that threatens to add Pollutants to the Waters of the Watershed System, the Person causing or contributing to the pollution or potential pollution shall notify the Commission and the Department immediately.

(2) *Watershed System*

(a) *General Regulations*.

1. Entrance on and exit from land of the Watershed System shall be made through gates or other designated areas.

2. No Person is allowed within any land of the Watershed System, except from one hour before sunrise to one hour after sunset, unless authorized by a written permit from the Commission or its designee.

3. Powered boats are prohibited within the Waters of the Watershed System except in areas designated by the Commission or its designee.

4. All acts which pollute or may pollute the water supply are prohibited. No litter or refuse of any sort may be thrown or left in or on any land or water within any Watershed System. All Persons within said System shall use the sanitary facilities provided for public use.

5. All acts which injure the property of the Commonwealth are prohibited. No Person shall injure, deface, destroy, remove or carry off any property, real or personal, under the care and control of the Commission, including but not limited to, all historic artifacts and natural materials. The removal of gravel, topsoil, stones, boulders, or other earthen material is prohibited from the Watershed System except for removal for official use for land management purposes by Commission staff. No Person shall build or construct any object or structure of the property of the Commonwealth except with the written permission of the Commission or its designee.

6. Cooking and all fires are prohibited within the Watershed System.

7. No Person shall wade or swim in any reservoir except wading while using boots for the purpose of launching boats at designated boat launch areas.

8. No Person shall wade or swim in any Tributary or Surface Waters on or within the property of the Commonwealth except at areas designated by the Commission or its designee.

9. Organized sports activities, including but not limited to orienteering and baseball, are prohibited in the Watershed System except by written permit from the Commission or its designee.

10. Any violation of 350 CMR 11.09 will be deemed sufficient cause for revocation of fishing privileges for a period of time not less than one year from the time of violation. The Commission and its employees are not responsible for any damage to or loss of property sustained by fishermen, or for any injury or loss of life which may be incurred in connection with public use of the reservoirs and Watershed System.

11. Breach of peace, profanity or other disorderly conduct offensive to the general public is strictly prohibited within the Watershed system. Possession of and drinking of alcoholic beverages is prohibited within said System.

12. No Person shall drive a motorized vehicle within the Watershed System except upon roads authorized for such use by the Commission or its designee. Recreational vehicles are prohibited on all Watershed System property except the use of snowmobiles in areas designated by the Commission or its designee. Motor vehicles shall be parked only in areas designated by the Commission or its designee. Operators of motor vehicles shall obey all regulatory signs unless otherwise directed by a police officer or person in charge. No Person shall willfully obstruct the free passage of vehicles or Persons within the Watershed System. Vehicle access for official use may be granted by the Commission or its designee.

13. No Person shall bring any animal within any Watershed System property except for horses and dogs at the Ware River Watershed at areas designated by the Commission or its designee.

14. The use of bicycles, skis and other means of non-motorized transportation within the Watershed system shall be permitted only in areas designated by the Commission or its designee.

15. No Person, except in an emergency, shall bring, land or cause to descend within any Watershed System property any aircraft except with a written permit from the Commission or its designee.

16. Parades, games, fairs, carnivals, fishing derbies, bazaars, gifts or solicitations for raising or collecting funds shall not be permitted within the Watershed System without written approval of the Commission or its designee.

17. Lotteries, raffles, gambling and games of chance are prohibited; and no Person shall have possession of machinery, instruments or equipment of any kind for use of same in the Watershed System.

18. Public assemblies of more than 25 persons shall not be allowed within the Watershed System without a written permit from the Commission or its designee.

19. No Person shall engage in any business, sale or display of goods or wares within the Watershed System without a written permit from the Commission or its designee.

20. Commercial signs and advertising are prohibited in the Watershed System.

21. No Person shall have possession of or discharge any weapon, firearm, fireworks, or other explosive on or within the Watershed System except at times and areas designated by the Commission or its designee. All forms of target shooting are prohibited on or within the Watershed System.

22. No Person may hunt, shoot or trap animals on or within any Watershed System property except at times and in areas designated by the Commission or its designee.

23. All Persons within the Watershed System shall obey the lawful directions of regulatory signs, police officers or persons in charge, or of Federal or Commonwealth wardens or enforcement officers.

24. The Watershed System or parts thereof may be closed for public access at the discretion of the Commission or its designee when necessary to protect the lands and waters under the care and control of the Commission.

25. The possession of all types of metal detectors or similar devices is prohibited on all of the Watershed System property.

(b) *Special Regulations for Quabbin Reservoir*.

1. Persons in compliance with Commonwealth Fish and Game Laws and Regulations, will be allowed to fish from shore in areas designated by the Commission or its designee. A valid state fishing or sporting license is required by any Person renting or launching a boat at any Commission facilities subject to 350 CMR 11.09. Reasonable fees for the use of boats, for rental of outboard motors for fishing purposes, or use of Commission facilities including parking and boat ramps, may be charged by the Commission.

2. Persons permitted to fish from boats shall, at all times, be responsible for the sanitary condition of the boats. Persons under 16 years of age must be accompanied by a Person possessing a valid fishing license in order to boat on Quabbin Reservoir.

3. Only boats of a minimum length of 12 feet, and of a type considered safe by the Commission representative in charge, shall be used. No inboard motors, collapsible boats, sailboats, pontoon boats, square sterned canoes, or other similar craft will be permitted in the water, and no boats will be permitted in the water except in areas designated for boating by the Commission or its designee. Outboard motors shall have a rating of not more than one-half the BIA or OBC rated horsepower for the boat and shall not exceed 20 horsepower, except that outboard motors for Commission boats less than fourteen 14 feet six inches in length shall not exceed ten horsepower. Boats less than 14 feet six inches in length will be limited to three occupants, and boats of that length and in excess thereof may be licensed to carry four occupants. No boats shall carry more than four occupants. Canoes and jon boats of a minimum length of 12 feet, and of a type considered safe by the Commission representative in charge, shall be used and only in areas designated for boating by the Commission on Pottapaug Pond above the regulating dam and at Gate 31 above the regulating dam. Canoes less than 16 feet and jon boats less than 14 feet six inches in length will be limited to two occupants, and canoes and jon boats in excess thereof may be licensed to carry three occupants. All boats must be in compliance with current Commonwealth Boating Laws. All boats must be clean and contain no refuse of any kind. Commission personnel shall have the right to inspect all private boats launched at Commonwealth facilities and may deny access in order to protect water quality or the safety of occupants. Chock blocks must be used on vehicles when removing boats from the Reservoir.

4. No Person shall operate a motor boat at a speed other than reasonable and proper or in such a manner as to annoy or endanger the occupants of other boats.

5. Fishing from the shorelines of the Quabbin Reservoir and its Tributaries within the Watershed System or from boats shall be allowed only during a season designated by

the Commission or its designee. All privately-owned boats, motors and other equipment must be removed from the property of the Commission each day.

6. Boats shall not leave the mooring areas before dawn, and must return at the time posted at each mooring area. The beaching of boats at any point except at the designated mooring and landing areas is strictly prohibited, except in cases of extreme emergency.

(c) *Special Regulations for Ware River*.

1. Persons in compliance with Commonwealth Fish and Game Laws and Regulations will be allowed to fish in the Ware River in areas designated by the Commission or its designee.

2. Powered boats and powered canoes are prohibited within the Ware River Watershed Reservation.

(d) *Special Regulations for Wachusett Reservoir*.

1. Persons in compliance with Commonwealth Fish and Game Laws and Regulations will be allowed to fish from the shore of Wachusett Reservoir in areas designated by the Commission or its designee.

2. Boating is prohibited in Wachusett Reservoir.

3. Fishing from the shoreline of the Reservoir shall be allowed only during a season designated by the Commission or its designee.

(e) *Special Regulations for Sudbury Reservoir*.

1. Persons in compliance with Commonwealth Fish and Game Laws and Regulations will be allowed to fish from the shore of Sudbury Reservoir in areas designated by the Commission or its designee.

2. Boating is prohibited on Sudbury Reservoir except in areas designated by the Commission or its designee.

11.10: Enforcement

Any Person who, without lawful authority, takes or diverts any Waters of the Watershed System or corrupts or defiles any such Waters or any source of such Waters or who violates and refuses to comply with any rule, regulation or order of the Commission shall be subject to the fines set forth in M.G.L. c. 92, ə 111. The provisions of 350 CMR 11.00 shall be enforced upon petition of the Commission or of any town or Person interested by the Supreme Judicial Court or Superior Court or any justice of either court as provided in M.G.L. c. 92, ə 112. In addition, upon written request by the Division, the Department shall have the authority to enforce the provisions of St. 1992 c. 36 and 350 CMR 11.00 by all legally permitted enforcement mechanisms including, but not limited to: issuing notices of noncompliance; convening pre-enforcement conferences; issuing water supply orders pursuant to M.G.L. c. 111, ə 160; and imposing administrative penalties pursuant to M.G.L. c. 21A, ə 16 and 310 CMR 5.00. Such written request by the Division to the Department may seek enforcement for a specified type of violation or area, for a designated group of cases or for an individual matter.

11.11: Miscellaneous

(1) Addresses - Offices of Division

Department of Conservation and Recreation
Quabbin Reservoir
485 Ware Road
Belchertown, Massachusetts 01007

Department of Conservation and Recreation
Wachusett Reservoir
P.O. Box 206
Clinton, Massachusetts 01510

(2) Address of Commissioner -

Department of Conservation and Recreation
251 Causeway Street, Suite 600
Boston, Massachusetts 02114

(3) Address of Department -

Department of Environmental Protection
Commonwealth of Massachusetts
Regional Division
One Winter Street
Boston, Massachusetts 02108

(4) Access to Property by Division - Any Person making a request for Watershed determination of applicability, an application for variance or a request for Exemption to the Division shall, upon request, allow the Division or its duly authorized representatives to inspect the property in question in order to assist the Division in the determination which is to be made. Personnel of the Division may enter, at reasonable times, any property, public or private, for the purpose of investigating or inspecting any condition relating to the discharge or possible discharge of Pollutants into the Watershed System and may make such tests as may be necessary to determine the existence and nature of such discharge as provided in M.G.L. c. 21, э 4.

11.12: Severability

If any provision or any part of 350 CMR 11.00 or the application thereof is held to be invalid, such invalidity shall not affect any other provision of 350 CMR 11.00.

11.13: Forms

Forms for use under the Watershed Protection Act shall be as follows:

Form 1 - Request for Watershed Determination of Applicability

Form 2 - Applicability Decision

Form 3 - Application for Variance

Form 4 - Variance Decision for Recording in Registry of Deeds

Form 5 - Request for Exemption of a Tributary

Forms 1, 3 and 5 and a Guidance Document, which may be of assistance in completing the forms, may be obtained from the Division at the addresses specified in 350 CMR 11.11(1) and (2).

REGULATORY AUTHORITY: 350 CMR 11.00: St. 1992, c. 36.

10.2.3 Watershed Management Plan Legislation

PART I. ADMINISTRATION OF THE GOVERNMENT

TITLE XIV. PUBLIC WAYS AND WORKS

CHAPTER 92A1/2. WATERSHED MANAGEMENT

Chapter 92A1/2: Section 16. Periodic watershed management plans

Section 16. The commissioner shall at least once every 5 years, adopt after public hearing one or more periodic watershed management plans for the watershed system, which shall have been prepared with the participation of a professionally qualified forester and the appropriate watershed advisory committee. Any watershed management plan shall provide for, but need not be limited to, forestry, water yield enhancement and recreational activities. All forestry activities shall be subject to sections 40 to 46, inclusive, of chapter 132.

10.2.4 Advisory Committee Legislation

PART I. ADMINISTRATION OF THE GOVERNMENT

TITLE XIV. PUBLIC WAYS AND WORKS

CHAPTER 92A1/2. WATERSHED MANAGEMENT

Chapter 92A1/2: Section 13. Quabbin watershed advisory committee

Section 13. The commissioner shall establish the Quabbin watershed advisory committee. The purpose of the committee shall be to advise the division on its policies and regulations regarding fishing, boating and other recreational activities and environmental, wildlife and habitat matters within the Quabbin watershed. The commissioner of the department shall appoint to the advisory committee 1 person from 3 names nominated by each of the following organizations: the Massachusetts Council of Sportsmen, the Trout Unlimited, the Quabbin Fisherman's Association, the Worcester County League of Sportsmen, the North Worcester County Quabbin Anglers, the Massachusetts Audubon Society, the Swift River Valley Historical Society, the Massachusetts Wildlife Federation, the New England Sierra Club, and the Friends of Quabbin, Inc.

The commissioner shall also appoint 1 member from the general public. The committee shall elect a chairperson from among its members, shall meet at least twice each calendar year, and may provide for alternate members to participate fully in its meetings whenever a regular member is unable to do so.

10.2.5 Deer Management Regulations

350 CMR 8.00: LAND WITHIN WATERSHED RESERVATIONS

Section

8.02: Deer Management Program in the Quabbin Reservoir Area

<u>8.02: Deer Management Program in the Quabbin Reservoir Area</u>

(1) Hunting of white-tailed deer shall be allowed in specified sections of the Quabbin Reservoir Area by those persons holding a use permit issued by the Commission or its designee for a controlled deer hunt conducted in conjunction with the Commission's Deer Management Program. All persons to whom such a use permit has been issued are also required to have a valid Massachusetts hunting license issued by the Division of Fisheries and Wildlife.

(2) The use permit will specify the hunting season, the time of day, and the designated location for hunting. Certain sensitive areas shall be designated off limits to permittees. Access to the hunting area shall be by use permit only and shall be for the season, time and designated location only.

(3) No hunting is allowed within direct view of the Quabbin Reservoir shoreline, or within 500 feet of any building, or in other areas posted as no hunt zones. Shooting or injury of any bird or animal species other than white-tailed deer is strictly prohibited.

(4) 321 CMR 3.00 applies to MDC controlled hunt programs. The use of buck shot is prohibited and firearms shall be limited to shotguns only. No cutting of branches, trees or shrubs, or nailing of trees is allowed. All deer carcasses shall be brought to a check station, tagged, and concealed from view before being transported outside of Commission property. In the event of a conflict, 350 CMR 8.00 takes precedence over 321 CMR 3.00.

(5) No litter or refuse of any sort may be thrown or left in or on any land or water within the Quabbin Reservoir Area. Sanitary facilities provided for public use shall be the only locations used for such purposes. No deer parts shall be disposed of within 100 feet of any brook, stream, wetland or other water body. All acts which may pollute the water supply are strictly prohibited. Permittees must obey all other promulgated Rules and Regulations of the Commission while on MDC lands.

(6) All public access, whether pedestrian or by motor vehicle, is restricted to paths and roads specifically designated for use during the hunting season. All vehicle parking must be in designated areas only.

(7) All persons within the Quabbin Reservoir Area shall obey the directions of regulatory signs, instructions contained on the use permit, and directions of police officers, Watershed Division employees, environmental police officers, rangers and enforcement officers.

(8) The selection of participants in the program shall be randomly accomplished. Once selected, applicants must attend a training session, certify that they have not violated M.G.L. c. 131 (Massachusetts Fisheries and Game laws) or M.G.L. c. 92 (Metropolitan District Commission) within the past five years, and pay all requisite fees, including a non-refundable $5.00 application fee, to participate in the hunting program. Use permits are valid only for the person named in the permit and for the period specified.

(9) Any person who violates or refuses to comply with any of 350 CMR 8.00 may be subject to immediate revocation of the permit, a criminal fine or imprisonment.

(10) The provisions of 350 CMR 8.00 are severable, and if any of them are held to be invalid for any reason or under any circumstance, such holding shall not affect any other rule or regulation.

REGULATORY AUTHORITY

350 CMR 8.00: M.G.L. c. 92, §§ 10 through 19; c. 92, §§ 104 through 120;
St. 1972, c. 737; St. 1990, c. 436.

10.3 Appendix III: Quabbin Flora

Quabbin Flora: Plant Species on Harvesting Lots

NOTE: this table includes species encountered by University of Massachusetts Herbarium staff during a 1995-6 survey of 37 proposed timber harvesting lots at Quabbin. It is not an exhaustive survey of all plants at Quabbin, although most common species as well as many of the less common species are represented. **Rare species are in bold.** *Invasive species are shown with an asterisk. This list is not meant to be comprehensive for the entire watershed, but serves as a starting point for assessing the diversity of plant species present on the Quabbin watershed.

Dicots

Acer pensylvanicum	Striped Maple
Acer rubrum	Red Maple
Acer saccharum	Sugar Maple
Achillea millefolium	common yarrow
Actaea pachypoda	doll's eyes
Actaea rubra	red baneberry
Actaea sp.	Baneberry
Alnus incana var. americana	speckled alder
Alnus serrulata	common alder
Amelanchier sp.	Shadbush
Amelanchier sp. (canadensis?)	
Amphicarpaea bracteata	hog peanut
Anemone quinquefolia	wood anemone
Anemonella thalictroides	rue anemone
Antennaria sp.	ladies' tobacco
Apios americana	groundnut
Apocynum androsaemifolium	spreading dogbane
Apocynum sp.	Dogbane
Aquilegia canadensis	wild columbine
Aralia nudicaulis	wild sarsaparilla
Aronia arbutifolia	cherry
Aronia melanocarpa	choke cherry
Asclepius sp.	Milkweed
Asclepius exaltata ?	green milkweed
Aster acuminatus	whorled aster
Aster cordifolius	heart-leaved aster
Aster divaricatus	white wood aster
Aster linariifolius	stiff leaf aster
Aster sp.	Aster
Aureolaria pedicularia	downy false foxglove
**Berberis thunbergii*	Japanese barberry
**Berberis vulgaris*	common barberry
Betula alleghaniensis	yellow birch
Betula lenta	black birch
Betula papyrifera	white birch
Betula populifolia	gray birch
Bidens sp.	Bur-Marigold
Boehmeria cylindrica	false nettle
Caltha palustris	marsh marigold
Cardamine sp.	Bitter cress
Carpinus caroliniana	iron wood
Carya ovata	shagbark hickory
Carya sp.	Hickory
Castanea dentata	chestnut
**Celastrus orbiculatus*	Japanese bittersweet
Chelone glabra	hairy turtlehead
Chimaphila maculata	spotted wintergreen
Chimaphila umbellata	pipsissewa
Chrysanthemum leucanthemum	white daisy
Chrysosplenium americanum	golden saxifrage
Circaea alpina	enchanters nightshade
Circaea lutetiana var. canadensis	Canadian en. night.
Clematis virginiana	virgin's bower
Collinsonia canadensis	richweed, stoneroot
Comptonia peregrina	sweet fern
Convolvulus sp.	Bindweed
Coptis trifolia	goldthread
Cornus alternifolia	alternate-leaf dogwood
Cornus canadensis	bunch berry
Cornus racemosa	red panicle dogwood
Cornus stoloniferous	red osier
Corydalis sempervivens	pale corydalis
Corylus americana	American hazelnut
Corylus cornuta	beaked hazelnut
Crataegus sp.	Hawthorn
Dalibarda repens	robin-run-away
Diervilla lonicera	bush honeysuckle
Epigaea repens	trailing arbutus
Eupatorium perfoliatum	boneset
Eupatorium rugosum	white snakeroot
Fagus grandifolia	beech
Fragaria sp.	Strawberry
Fraxinus americana	white ash
Fraxinus pennsylvanica	green ash
Fraxinus sp.	Ash
Galium lanceolatum	lance-leaved wild licorice

Galium sp.	Bedstraw
Galium trifidum	three-cleft bedstraw
Gaultheria procumbens	wintergreen
Gaylussacia baccata	black huckleberry
Gaylussacia frondosa	dangleberry
Gaylussacia sp.	Huckleberry
Geranium maculatum	wild geranium
Gerardia sp.	Gerardia
Geum canadense	Canadian avens
Glechoma hederacea	ground ivy
Gnaphalium sp.	Cudweed
Hamamelis virginiana	witch hazel
Helianthemum sp.	rockrose
Hieracium venosum	rattlesnake weed
Hedyotis caerula	bluets
Hydrocotyle americana	water-pennywort
Hypericum sp.	St. John's wort
Ilex verticillata	winterberry
Impatiens capensis	jewelweed
Kalmia angustifolia	sheep laurel
Kalmia latifolia	mountain laurel
Lactuca canadensis	wild lettuce
Lespedeza sp.	Bush-clover
Lindera benzoin	spicebush
**Lonicera sp.*	Honeysuckle
**Lonicera tatarica*	tartarian honeysuckle
Lycopus sp.	Water horehound
Lyonia ligustrina	maleberry
Lysimachia ciliata	hairy loosestrife
Lysimachia quadrifolia	whorled loosestrife
Lysimachia terrestris	swamp candles
Malva neglecta?	common mallow
Melampyrum lineare	cow wheat
Mimulus ringens	gaping monkey flower
Mitchella repens	partridge berry
Moneses uniflora	One-flowered Pyrola
Monotropa hypopithys	pine-sap
Monotropa uniflora	Indian-pipe
Myosotis scorpioides	true forget-me-not
Myrica gale	sweet gale, meadow-fern
Rorippa nasturtium-aquaticum	watercress
Nemopanthus mucronatus	mountain holly
Nyssa sylvatica	black gum
Orobanche uniflora	one-flowered cancer-root
Ostrya virginiana	American hop-hornbeam
Oxalis Montana	common wood sorrel
Oxalis sp.	Wood sorrel
Panax trifolius	dwarf ginseng
Parthenocissus quinquefolia	Virginia creeper
Parthenocissus sp.	Virginia creeper
Plantago sp.	Plantain
Polygala paucifolia	fringed polygala
Polygonum sagittatum	Tearthumb
Populus grandidentata	large-toothed aspen
Populus sp.	Aspen
Populus tremuloides	quaking aspen
Potentilla canadensis	Canadian cinquefoil
Potentilla simplex	old-field cinquefoil
Potentilla sp.	Cinquefoil
Prenanthes alba	white snake root
Prenanthes sp.	Rattlesnake root
Prenanthes trifoliolata	gall-of-the-earth
Prunella vulgaris	heal all
Prunus serotina	black cherry
Prunus sp.	Cherry
Prunus virginiana	choke cherry
Pyrola elliptica	shinleaf
Pyrola rotundifolia	round-leafed pyrola
Pyrola sp.	Pyrola
Pyrus malus	apple
Quercus alba	white oak
Quercus coccinea	scarlet oak
Quercus ilicifolia	scrub oak
Quercus prinus	chestnut oak
Quercus rubra	red oak
Quercus sp.	Oak
Quercus velutina	black oak
Ranunculus recurvatus	buttercup
Ranunculus sp.	Buttercup
**Rhamnus cathartica*	common buckthorn
Rhododendron sp.	Rhododendron, Azalea
Rhododendron viscosum	swamp honeysuckle
Rhus copallina	Winged sumac
Toxicodendron radicans	poison ivy
Rhus typhina	staghorn sumac
**Rosa multiflora*	multiflora rose
Rosa rugosa	Rugosa Rose
Rosa sp.	Rose
Rubus allegheniensis	black raspberry
Rubus flagellaris	dewberry
Rubus hispidus	swamp dewberry
Rubus idaeus	raspberry
Rubus sp.	Blackberry
Rumex acetocella	sorrel
Sambucus canadensis	common elder
Sambucus pubens	stinking elder
Sanguinaria canadensis	bloodroot

Sanicula marilandica	black snakeroot
Sassafras albidum	sassafras
Saxifraga pensylvanica	swamp saxifrage
Scutellaria epilobiifolia	common skullcap
Sedum purpureum	garden orpine
Senecio aureus	squaw weed
Solanum dulcamara	nightshade
Solidago caesia	blue-stem goldenrod
Euthamia graminifolia	grass-leaved goldenrod
Solidago sp.	Goldenrod
Sorbus sp.	
Specularia sp.	Venus' looking glass
Spiraea alba var. latifolia	meadowsweet
Spiraea sp.	Spiraea
Spiraea tomentosa	steeple bush
Symphoricarpos albus	snowberry
Taraxacum sp.	
Thalictrum polygamum	tall meadow rue
Thalictrum sp.	Meadow rue
Tiarella cordifolia	foam flower
Tilia americana	basswood
Trientalis borealis	starflower
Ulmus americana	American elm
Vaccinium angustifolium	low-bush blueberry
Vaccinium corymbosum	high-bush blueberry
Vaccinium macrocarpon	American cranberry
Vaccinium sp.	Blueberry
Vaccinium pallens	early sweet blueberry
Veronica scutellata	marsh speedwell
Viburnum acerifolium	maple-leafed viburnum
Viburnum alnifolium	hobblebush
Viburnum cassinoides	witherod
Viburnum dentatum var. lucidum	southern arrow wood
Viburnum lentago	nannyberry
Viburnum opulus var. americanum	highbush cranberry
Viola conspersa	dog violet
Viola cucullata	marsh violet
Viola fimbriatula	fringed violet
Viola macloskii ?	
Viola sp.	Violet
Vitis sp.	Grape
Zizia aurea	golden alexander

Monocots

Anthoxanthum odoratum	sweet vernal grass
Arisaema sp.	jack-in-the-pulpit
Arisaema triphyllum	small jack-in-the-pulpit
Brachyelytrum erectum	
Calamagrostis canadensis	blue-joint
Carex canescens	
Carex communis	
Carex crinita	long-haired sedge
Carex debilis	weak sedge
Carex digitalis	finger-like sedge
Carex disperma	two-seeded sedge
Carex folliculata	follicle-bearing sedge
Carex gracillima	slender sedge
Carex intumescens	swelled-up sedge
Carex laxiflora	loosely-flowered sedge
Carex (laxiflora group)	
Carex leptalea	delicate sedge
Carex lurida	sallow sedge
Carex novae-angliae	New England sedge
Carex (ovales group)	
Carex pen/communis	
Carex pensylvanica	Penn. sedge
Carex platyphylla?	broad-leaved sedge
Carex sp.	Sedge
Carex (stellulatae group)	
Carex stricta	erect sedge
Carex stipata	crowded sedge
Carex swanii	Swan sedge
Carex trisperma?	three-seeded sedge
Carex vestita	clothed sedge
Carex vulpinoidea	foxtail-flowered sedge
Clintonia borealis	yellow clintonia
Corallorhiza sp.	coral root
Cypripedium acaule	pink lady's slipper
Danthonia spicata	junegrass
Epipactis helleborine	helleborine
Festuca ovina	sheep festcue
Glyceria pallida	pale manna-grass
Glyceria sp.	manna-grass
Glyceria striata	fowl-meadow grass
Goodyera pubescens	rattlesnake plantain
Goodyera sp.	Plantain
Goodyera tesselata	checkered rattlesnake plantain
[Grass species]	
Habenaria bracteata	
Habenaria clavellata	green woodland orchis
Habenaria fimbriata	large purple-fringed orchis
Habenaria sp.	Orchis
Hypoxis hirsuta	stargrass
Iris versicolor	blue flag
Isotria verticillata	large whorled pogonia
Juncus effusus	soft rush
Lilium philadelphicum	wood lily

Lilium sp.	Lily
Luzula sp.	Woodrush
Maianthemum canadense	Canada mayflower
Medeola virginiana	Indian cucumber root
Orchid sp.	Orchid
Oryzopsis sp.	rice grass
Panicum latifolium	panic grass
Panicum sp.	panic grass
Polygonatum pubescens	hairy Solomon's seal
Saggitaria sp.	Arrowhead
Scirpus cyperinus	wool sedge
Scirpus expansus	spread-out bulrush
Scirpus sp.	Bulrush
Sisyrinchium sp.	Blue-eyed grass
Smilacina racemosa	false solomon's seal
Smilax herbacea	Jacob's ladder
Smilax rotundifolia	common greenbrier
Symplocarpus foetidus	skunk cabbage
Trillium sp.	Trillium
Trillium undulatum	painted trillium
Typha sp.	Cat-tail
Uvularia perfoliata	bellwort
Uvularia sessilifolia	wild oats
Veratrum viride	false hellebore

Fern Allies

Equisetum sp.	Horsetail
Equisetum arvense	common horsetail
Equisetum sylvaticum	horsetail
Diphasiastrum digitatum	trailing evergreen
Diphasiastrum tristachyum	ground pine
Huperzia lucidula	shiny clubmoss
Lycopodium annotinum	bristly clubmoss
Lycopodium clavatum	common clubmoss
Lycopodium dendroideum	
Lycopodium hickeyi	
Lycopodium obscurum	tree clubmoss

Ferns

Adiantum pedatum	maiden-hair fern
Asplenium platyneuron	
Athyrium filix-femina	lady fern
Athyrium thelypteroides	silvery spleen
Botrychium dissectum	dissected grape fern
Botrcyhium matricariaefolium?	Matricaria-leaved g.f.
Botrychium multifidum	leathery grape-fern
Botrychium simplex?	simple grape-fern
Botrychium virginianum	rattlesnake fern
Dennstaedtia punctilobula	hay-scented fern
Dryopteris cristata	crested wood fern
Dryopteris intermedia	spinulose wood fern
Dryopteris marginalis	marginal shield fern
Dryopteris spinulosa	spinulose wood fern
Onoclea sensibilis	sensitive fern
Osmunda cinnamomea	cinnamon fern
Osmunda claytoniana	interrupted fern
Osmunda regalis	royal fern
Polypodium virginianum	rock polypody
Polystichum acrostichoides	Christmas fern
Pteridium aquilinium	bracken fern
Thelypteris noveboracensis	New York fern
Thelypteris palustris	marsh fern
Thelypteris phagopteris	beech fern
Thelypteris simulata	Massachusetts fern

Gymnosperms

Juniperus communis	common juniper
Juniperis virginiana	red cedar
Picea glauca	white spruce
Picea rubens	red spruce
Pinus banksiana	Jack pine
Pinus resinosa	red pine
Pinus rigida	pitch pine
Pinus strobus	white pine
Taxus canadensis	American yew
Tsuga canadensis	hemlock

10.4 Appendix IV: 2004 Quabbin Regeneration Summary Report

Quabbin Forest Regeneration Sampling - Brief History

Past efforts: We have been systematically monitoring regeneration at Quabbin since 1988. Our main method includes milacre (1/1,000th acre) circular plots taken every 200 feet along randomly selected E-W or N-S transects. This is technically *two-stage (transects and sampling points along transects) cluster sampling with uneven-sized clusters (transects are of varying lengths)*. During the period from 1989 through 1996, we conducted watershed-wide sampling, retrieving data from all blocks and all forest types / conditions. We expanded the number of transects in 1996, in a successful effort to reduce the standard error associated with these data Because regeneration numbers and species distribution are changing gradually, we moved from an annual survey of all areas to a rotation, between 1997 and 2003. In full watershed surveys, we collect information from approximately 2,000 plots requiring the foresters to walk total distances in excess of 100 miles.

Following is a summary of our efforts:

1988: Preliminary sampling on a selection of CFI plots
1989: 796 plots from transects throughout the Quabbin properties
1991 to 1996: Regeneration surveys completed for all blocks each year except 1992; in 1996, 50 transects were sampled, yielding 1,808 forested plots (plots that fell on roads, in wetlands, etc. were not analyzed)
1997: Surveyed all on-Reservation plots for Prescott and New Salem and all off-Reservation plots on all blocks.
1998: Surveyed all on-Reservation plots in Pelham, Hardwick, and New Salem
1999: Surveyed all on-Reservation plots in Petersham and Prescott
2000-2001: Completed the decadal remeasurement of our 300+ 1/5th acre Continuous Forest Inventory plots, including 10 milacre regeneration plots per CFI plot
2001-2002: Surveyed all on-Reservation plots on Prescott and Pelham
2003: Due to staff reductions, reorganization, green certification, and other extenuating circumstances, we did not complete regeneration transects
2004: Full watershed survey conducted, sampling from 1,946 milacre plots distributed across 50 transects of varying widths, covering all blocks and areas both within and outside of the Reservation

In addition to the above, we have conducted browsing surveys on sprout areas produced by cutting of small diameter hardwoods. For these surveys, we count up to 100 twigs/buds per clump, noting whether they are browsed or intact. Results of these browsing surveys are highly variable. The recent increase in the moose population is further confounding regeneration transects and browsing surveys.

A summary report for regeneration and browsing surveys was produced in 1997 to inform the discussion of the next phase of deer impact control. The results showed dramatic increases in the overall growth and development of regeneration as a result of deer reduction, but some continuing disappointments in species distribution; in particular the predominance of two species – white pine and black birch – versus a much more balanced species distribution in off-Reservation areas where hunting has been continuous.

2004 effort: The Natural Resources and Quabbin Section Forestry staffs designed and completed a watershed-wide regeneration survey in 2004. This comprehensive survey was required to address several concerns, including the need to better understand why the deer hunt was so unusually productive in Petersham in 2003, the need to continue to monitor progress in both numbers and species composition, and the need to benchmark the status of regeneration as the moose population begins to have an effect on our forest.

For 2004, we laid out 50 transects, designed to sample both on and off-Reservation in all five blocks. These lines included 16 new transects randomly selected from within the strata that includes harvesting that occurred within the past 3 to 7 years (the time period during which we expect regeneration to begin to appear on harvested lots), and 34 transects that were measured in 1996 and subsequent years. Transect length ranged from approximately ½ mile to just shy of 5 miles. In the past, we identified plots as either light-limited, sufficiently open to establish regeneration, or sufficiently open to allow regeneration to grow and develop. In response to some concern about the subjectivity of our determination of light levels, we dropped this measurement from our plot data collection in 2004. Mean values are derived by block and general forest overstory type, mixing all light levels. We have regrouped and analyzed the 1989 and 1994 data in the same manner to enable a direct comparison of these data sets. (NOTE: A map of the 2004 transects is included at the back of this document for reference.)

The 2004 sample included 156 plots outside the reservation and 1,790 within the reservation. The sample size off-Reservation was small, meant simply to confirm previous findings from continuously hunted areas. Based on the simple comparison in **Table 1**, the areas within the Reservation now contain generally higher regeneration numbers than off-Reservation, except that sapling sized regeneration (defined as trees 1" to 5.5" in diameter at breast height) is still about twice as abundant off-Reservation. This discrepancy is likely to become less pronounced as the on-Reservation regeneration grows older, gradually increasing in size and falling in total numbers due to competition and stem exclusion. Both on and off-Reservation areas currently support in excess of 1,300 stems per acre greater than 4.5 feet in height. (Note that the 1989 regeneration target of 2,000 stems per acre greater than 4.5 feet tall was based exclusively on plots designated as "disturbed", in which regeneration numbers are higher.)

Table 1: 2004 Comparison Off versus On Reservation

Location	Data	Per Acre
Off Reservation	Average of Tot >1<4.5	2,071
	Average of Tot >4.5<sap	776
	Average of Tot sap	628
	Average all sizes	*3,474*
On Reservation	Average of Tot >1<4.5	3,187
	Average of Tot >4.5<sap	1,008
	Average of Tot sap	336
	Average all sizes	*4,532*
Total Average of Tot >1<4.5		3,098
Total Average of Tot >4.5<sap		990
Total Average of Tot sap		359
	Average all sizes	*4,447*

Table 2: 2004 Regeneration Summary By Block

Block	Data	Off Res	On Res	Combined
Pelham	Average of Tot >1<4.5	1,122	2,102	1,962
	Average of Tot >4.5<sap	735	542	570
	Average of Tot sap	755	359	416
	Average of Tot >4.5	1,490	902	985
	Average of Tot all	2,612	3,003	2,948
Hardwick	Average of Tot >1<4.5	3,000	2,634	2,653
	Average of Tot >4.5<sap	433	950	914
	Average of Tot sap	167	283	274
	Average of Tot >4.5	600	1,233	1,188
	Average of Tot all	3,600	3,867	3,841
Prescott	Average of Tot >1<4.5	-	3,267	3,267
	Average of Tot >4.5<sap	-	1,054	1,054
	Average of Tot sap	-	277	277
	Average of Tot >4.5	-	1,331	1,331
	Average of Tot all	-	4,597	4,597
New Salem	Average of Tot >1<4.5	1,733	3,399	3,012
	Average of Tot >4.5<sap	1,067	460	601
	Average of Tot sap	717	490	543
	Average of Tot >4.5	1,783	949	1,143
	Average of Tot all	3,517	4,348	4,155
Petersham	Average of Tot >1<4.5	4,353	4,441	4,438
	Average of Tot >4.5<sap	471	1,668	1,616
	Average of Tot sap	765	375	392
	Average of Tot >4.5	1,235	2,043	2,008
	Average of Tot all	5,588	6,484	6,445
Total Average of Tot >1<4.5		2,071	3,187	3,096
Total Average of Tot >4.5<sap		776	1,008	989
Total Average of Tot sap		628	336	359
Total Average of Tot >4.5		1,404	1,344	1,348
Total Average of Tot all		3,474	4,532	4,445

There are some interesting differences in the regeneration conditions among the five administrative Blocks at Quabbin, shown in Table 2 above and Table 3 below. Within the Reservation, Pelham continues to yield the lowest mean values for regeneration, with 902 stems per acre above 4.5 feet, and just over 3,000 total. On-Reservation sites in Petersham, on the other hand, contain 2,043 stems above 4.5 feet, and 6,484 stems of all sizes, per acre, on average. The largest *changes* in these values have been on Prescott Peninsula, where deer pressure was at its highest in estimates during the years just prior to the first MDC deer hunt. There was virtually no regeneration greater than one foot in height on large areas of the Peninsula in 1989. In 1996, on disturbed plots, there were 1,677 stems per acre above 1 foot in height, and just 81 stems greater than 4.5 feet in height, on average, on the Peninsula. By 2004, these numbers have changed dramatically, with an average of 4,597stems per acre greater than 1 foot, of which 1,331 were greater than 4.5 feet. These changes are summarized in Table 3 and accompanying graphics below.

Table 3: Comparison of averages, 1989, 1994, 2004

Block	Year	1' to 4.5'	> 4.5'	TOTAL
Off Reservation	1989	1,960 /acre	1,140 /acre	3,100 /acre
	1994	2,750	1,840	4,590
	2004	2,071	1,404	3,475
On Reservation	1989	770	130	910
	1994	2,955	417	3,372
	2004	3,187	1,344	4,531
Hardwick	1994	1,840	581	2,421
	2004	2,634	1,333	3,967
New Salem	1994	3,846	212	4,058
	2004	3,399	950	4,349
Pelham	1994	930	71	1,001
	2004	2,102	901	3,001
Petersham	1994	4,369	1,054	5,423
	2004	4,438	2,008	6,446
Prescott	1994	3,789	167	3,956
	2004	3,267	1,331	4,598

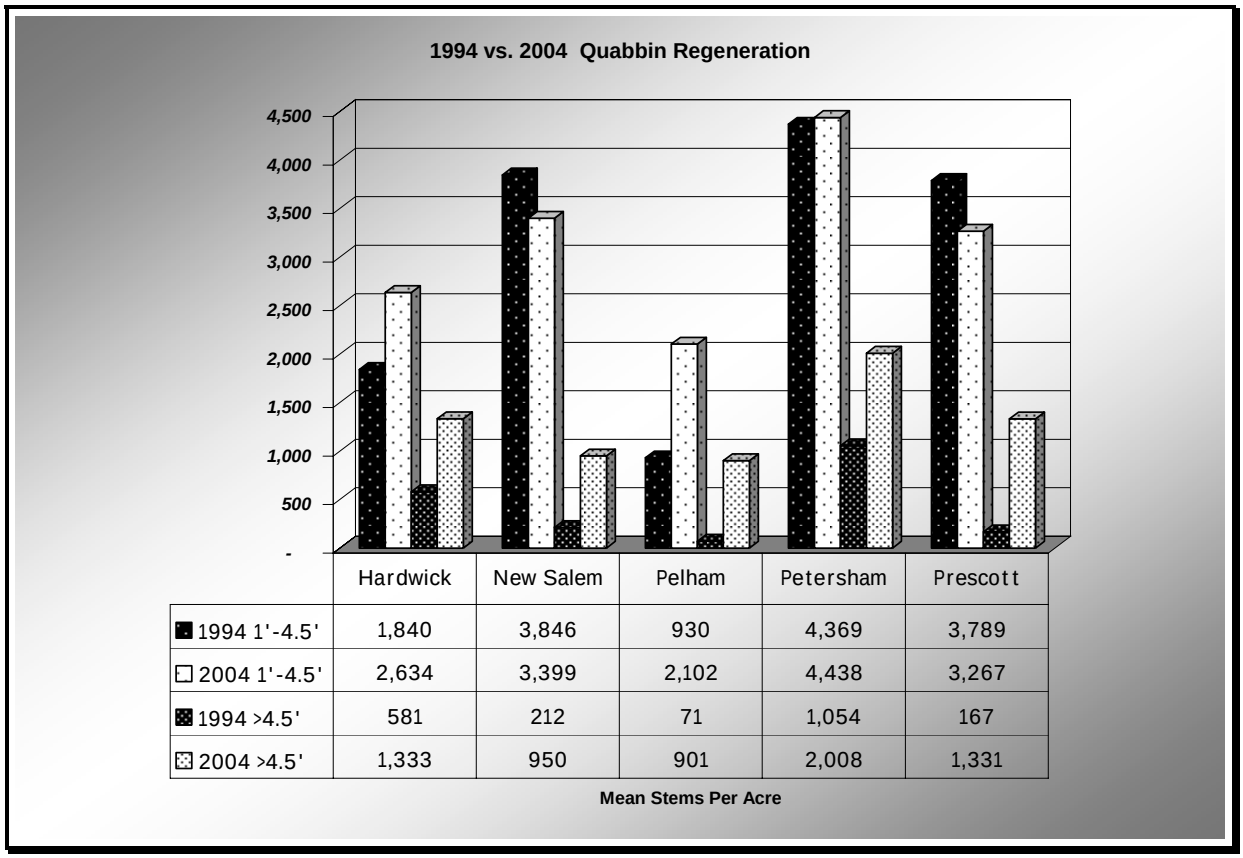


Table 4: Species comparison

Off Reservation	Block Pelham	Hardwick	Prescott	New Salem	Petersham	Total By Size	Total All sizes
WP > 1 foot	224	767	-	483	2,294	654	-
WP > 4.5 feet	102	33	-	533	235	269	-
WP Sapling	61	33	-	133	588	141	1,064
HK > 1 foot	122	-	-	400	59	199	-
HK >4.5	20	-	-	133	-	58	-
HK Sap	61	-	-	183	-	90	346
BIR >1	20	33	-	333	294	173	-
BIR >4.5	184	100	-	200	59	160	-
BIR Sap	143	67	-	233	59	154	487
MAP >1	61	933	-	183	588	333	-
MAP >4.5	122	133	-	33	59	83	-
MAP Sap	163	33	-	50	118	90	506
OAK >1	327	400	-	150	647	308	-
OAK >4.5	20	33	-	-	59	19	-
OAK Sap	-	33	-	-	-	6	333
ASH >1	-	167	-	17	118	51	-
ASH >4.5	-	33	-	-	59	13	-
ASH Sap	-	-	-	33	-	13	77
OTH > 1	367	700	-	167	353	353	-
OTH >4.5	286	100	-	167	-	173	-
OTH Sap	327	-	-	83	-	135	660
Tot >1<4.5	1,122	3,000	-	1,733	4,353	2,071	-
Tot >4.5<sap	735	433	-	1,067	471	776	-
Tot sap	755	167	-	717	765	628	-
Tot all	2,612	3,600	-	3,517	5,588	3,474	-
On Reservation	-	-	-	-	-	-	-
WP > 1 foot	959	929	1,353	1,884	1,976	1,378	-
WP > 4.5 feet	224	458	385	263	854	461	-
WP Sapling	173	64	88	247	176	132	1,971
HK > 1 foot	115	64	64	359	136	120	-
HK >4.5	27	12	8	25	5	13	-
HK Sap	7	10	-	86	-	13	146
BIR >1	319	399	311	409	500	383	-
BIR >4.5	115	221	317	116	463	269	-
BIR Sap	44	62	78	71	53	63	715
MAP >1	261	264	397	465	691	413	-
MAP >4.5	51	59	68	25	157	77	-
MAP Sap	68	62	62	30	88	65	554
OAK >1	220	561	631	197	899	555	-
OAK >4.5	3	55	54	5	80	46	-
OAK Sap	-	7	4	5	16	7	608
ASH >1	27	67	212	25	82	99	-
ASH >4.5	3	12	44	5	24	21	-
ASH Sap	-	12	4	-	8	6	126
OTH > 1	200	352	299	61	157	239	-
OTH >4.5	119	133	178	20	85	121	-
OTH Sap	68	67	40	51	35	51	410
Tot >1<4.5	2,102	2,634	3,267	3,399	4,441	3,187	-
Tot >4.5<sap	542	950	1,054	460	1,668	1,008	-
Tot sap	359	283	277	490	375	336	-
Tot all	3,003	3,867	4,597	4,348	6,484	4,532	-

Quabbin Park has been excluded from the Quabbin deer hunt due to heavy recreational uses in this area. We ran two transects through Quabbin Park in 2004, collecting data from 75 plots. These lines and plots were run through the managed area of the Park, and deliberately placed to intersect areas harvested in the last 5-12 years. Consequently, these figures do not represent the western areas of the Park, which fall within the Areas with Special Management Restrictions. Table 5 summarizes the averages for these plots. Overall, regeneration greater than 4.5 feet is similar in number to other areas within the Reservation. However, 88% of this regeneration is white pine. Furthermore, only 3 plots out of 75 had *any* white pine regeneration greater than 4.5 feet tall; the high mean is the result of two plots, which had 48 and 33 stems of white pine greater than 4.5 feet. Regeneration from one foot tall to 4.5 feet tall totals just 716 stems, on average, which is only 22.5% of the average for the Reservation as a whole, and only 12% of the plots had *any* white pine regeneration in this class. While white pine seems to be able to make it in limited areas, there is extremely poor success by any other species in getting to and above 4.5 feet (the deer browse level).

Table 5: Quabbin Park averages

Data	Per Acre Average
WP >1	405
WP >4.5	1,189
WP Saplings	162
HK >1	-
HK >4.5	-
HK Saplings	-
BIRCH >1	14
BIRCH >4.5	-
BIRCH Saplings	-
MAPLE >1	27
MAPLE >4.5	14
MAPLE Saplings	27
OAK >1	270
OAK >4.5	14
OAK Saplings	-
ASH >1	-
ASH >4.5	-
ASH Saplings	27
OTHER > 1	-
OTHER >4.5	54
OTHER Saplings	54
Total > 1	**716**
Total >4.5	**1,271**
Total Saplings	**270**
Total All Sizes	**2,257**

Summary Conclusions:

1. Overall, tree regeneration within the "Reservation" has made a remarkable recovery from the exceptionally low averages in 1989 (total combined average for all sizes was just 910 stems per acre) to those in the most recent, 2004 inventory (combined average 4,532, a 500% increase).

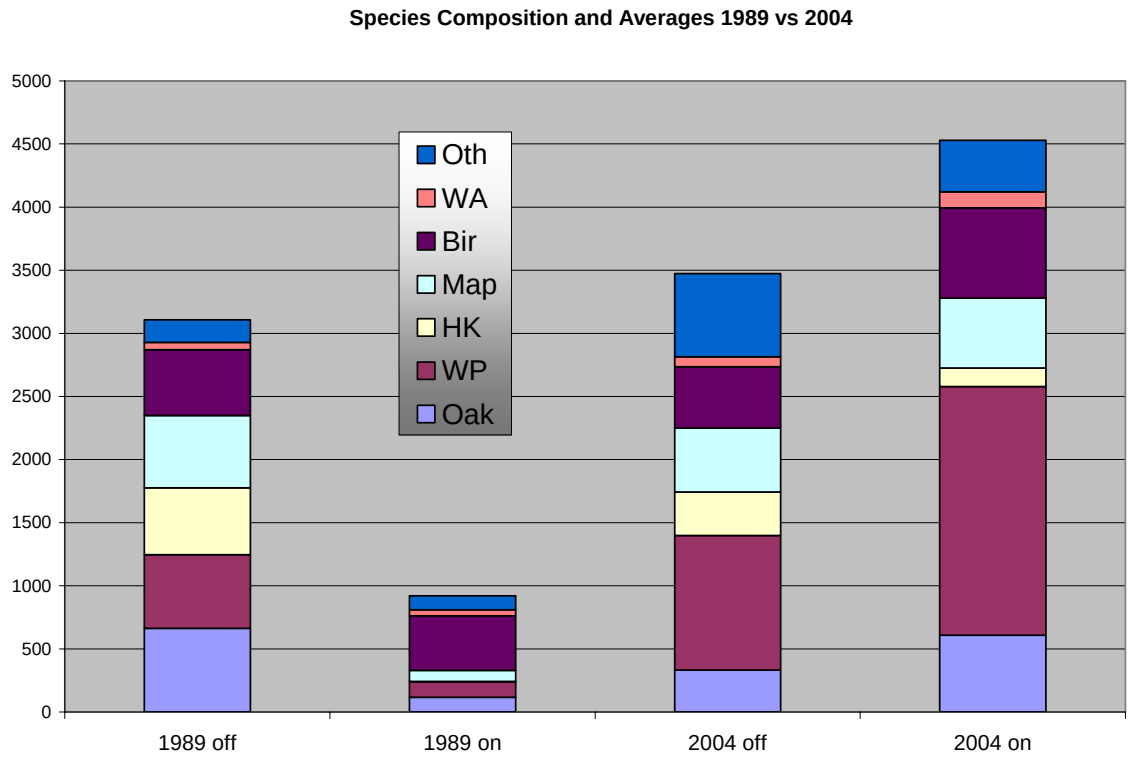
2. The average total number of stems of regeneration within the Reservation (4,532 per acre) is now greater than in areas that have been continuously hunted off-Reservation (current average 3,475 stems per acre). However, the vast majority of the extra numbers within the Reservation are in the 1 foot to 4.5 foot category, and there are twice as many saplings (stems 1" to 5.5" diameter at breast height) off-Reservation. This is indicative of the recovery from a long-term suppression of regeneration. In off-Reservation areas where regeneration has not been suppressed, the size-class distribution of regeneration follows a typical pattern, with a gradual decline in the numbers in each age/size cohort due to stem exclusion. Within the Reservation, there remains a bubble in the youngest age/size class and the numbers in the sapling size as the older classes are still catching up after decades of not being replaced.

3. While regeneration within the Reservation in the Pelham block is the lowest of all block averages, it is very close to the overall average for off-Reservation areas (3,003 stems in Pelham versus 3,474 for off-Reservation areas). Within the Reservation, the average number of stems in the sapling class ranges from 277 per acre on Prescott to 490 in New Salem, versus an off-Reservation average of 628. Petersham is currently carrying the highest overall regeneration both on and off-Reservation, with averages of 5,588 stems per acre off-Reservation and 6,484 stems per acre on-Reservation.

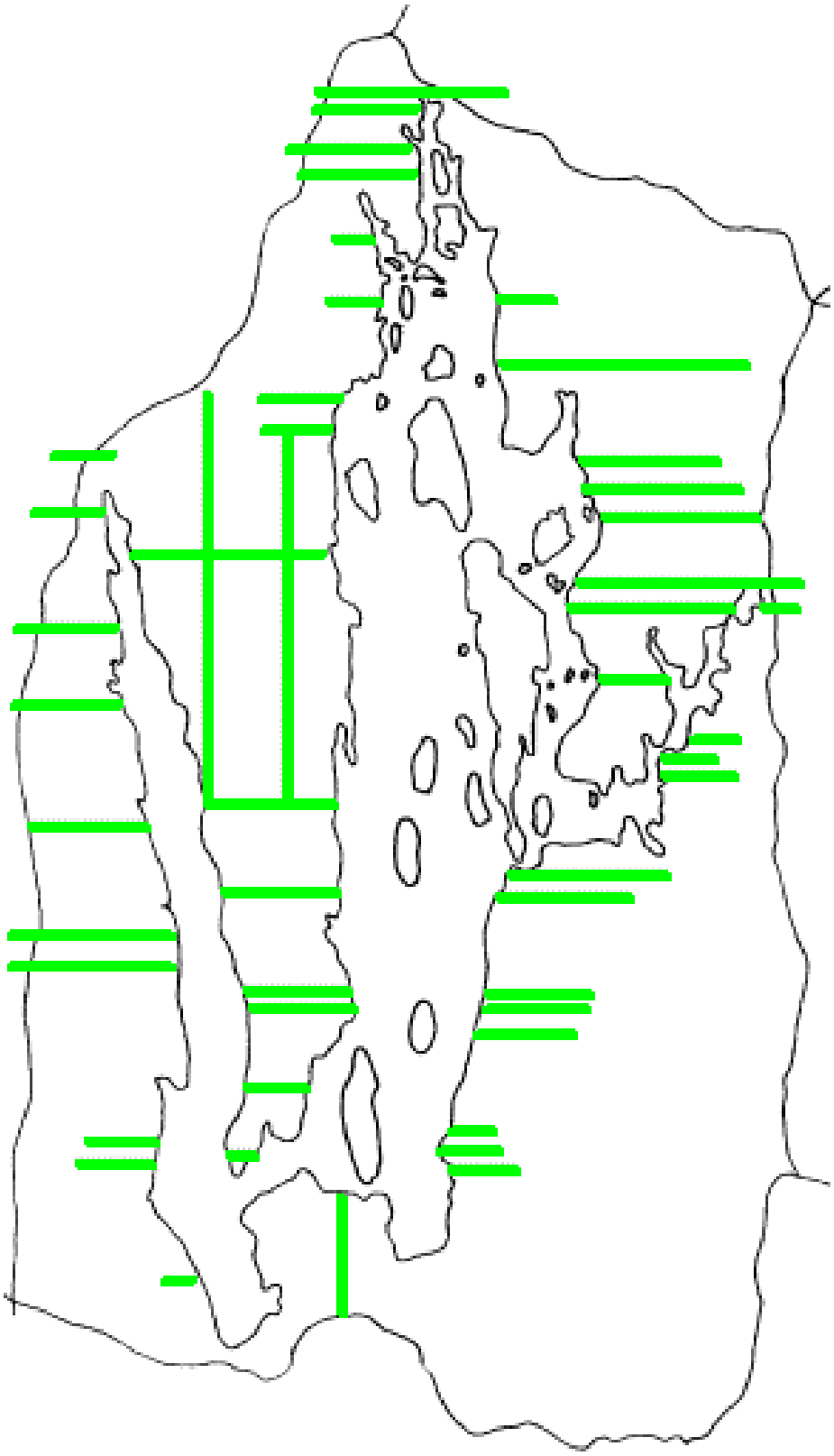
4. In the 1989 regeneration report, regeneration greater than 4.5 feet across all light/disturbance levels averaged 1,140 stems per acre off-Reservation and just 130 stems per acre within the Reservation. In 2004, the average in this size class was 1,404 in off-Reservation areas and 1,344 in all areas within the Reservation, including 628 and 336 stems, respectively, in the 1" to 5.5" dbh "sapling" category, which was not included in the 1989 data. As indicated above, while these total numbers for regeneration greater than 4.5 feet in height are now very similar for both on and off-Reservation areas, they differ in that on-Reservation areas average about 200 more stems in the 4.5 foot tall to 1" inch dbh class, and about 300 fewer stems in the larger, 1" to 5.5" size class.

5. Quabbin Park, to the extent that it was surveyed in 2004, contains very little regeneration other than white pine. While very high values for white pine on a few plots skewed the average, the vast majority of plots in the Park contained no tree regeneration of any species.

6. Species composition across the Reservation, in addition to overall volume of regeneration, has changed dramatically since 1989. White pine continues to dominate all other species, both within and outside the Reservation. Black birch is the second most common species within the Reservation, although most other species inside are now approaching or exceeding the numbers outside the Reservation. There were almost twice as many oaks and white ash inside as there were outside the Reservation in 2004. Hemlock regeneration on the inside, nearly absent in the 1989 measurement, was almost half the average value on the outside. In 1989, maples were scarce inside the Reservation, but are now approximately the same inside and out. The following charts provide details of changes in both composition and average numbers of stems for 1989 versus 2004.



	Oak	WP	HK	Maples	Birches	WA	Other
1989 off Res	663	584	530	573	521	58	179
1989 on Res	116	124	1	87	433	48	111
2004 off Res	333	1064	346	506	487	77	660
2004 on Res	608	1971	146	554	715	126	410



2004
Regeneration
Transects

10.5 Appendix V: Technical Assistance to Communities: Projects 1994-2006

DIRECT TECHNICAL ASSISTANCE PROVIDED TO QUABBIN & WARE RIVER WATERSHED TOWNS BY THE QUABBIN ENVIRONMENTAL PLANNING SECTION STAFF: 1994-2006

Note: Projects in bolded text are ongoing as of 9/21/06.

All Towns
• Zoning Reform Working Group (model state statutes and educational materials for all towns)
• Summary of Selected Growth Management Tools (guidebook for all planning boards)
• Housing and Land Use in Central Massachusetts (research publication of regional interest)
• Location of Road Rights-of-Way (model subdivision regulation sent to all towns)
• Citizen Planner Training Collaborative (ANR and growth management workshops)
• Periodic informational mailings to all watershed planning boards
• Research and development of list service for watershed land use boards (BI, PB, CC BOH, ZBA)

Shutesbury, MA (many models developed here and adapted for use in other watershed towns)
• Lake Wyola drainage designs (w/ EQ Section)
• Subdivision Control Regulations revisions (new sections)
• Town-wide Rate of Development Bylaw (original)
• Back-Lot Bylaw (adapted from Buckland, MA model)
• Cell Tower Bylaw (from various models)
• Town Center Study (Conway School of Landscape Design)
• Advice to Zoning Board of Appeals, Planning Board and Building Inspector
• Project review and recommendations to Planning Board, Zoning Board of Appeals, and Building Inspector
• Technical review of zoning revisions (work performed by outside consultant)

Petersham, MA
• Subdivision Control Regulations (full set)
• Subdivision Control Regulations (revised full set)
• Town-wide Rate of Development Bylaw (from Shutesbury, MA model)
• Gravel Removal Bylaw (from MDC model)
• Advice to Planning Board and Master Plan Subcommittee (implementation element of master plan)
• Proposed zoning amendments (review and recommendations)

Phillipston, MA
• Subdivision Control Regulations (review, recommendations)
• Subdivision Control Regulations (developed full set of new regulations)
• Gravel Removal Bylaw (from MDC model)
• General advice to Planning Board
• Project review and recommendations

Templeton, MA
• Advice to Conservation Commission and Building Inspector

Hubbardston, MA
• Town-wide Rate of Development Bylaw (from Shutesbury, MA model and others, editing)
• Town-wide Rate of Development Bylaw (revisions after Zuckerman v. Hadley SJC decision)
• Review of existing master plan
• Subdivision Control Regulations (provided models from Shutesbury, MA)
• Advice to Planning Board, Building Inspector and Open Space Committee
• Project review and recommendations

• Aquifer Protection Bylaw (provided model bylaw)
• Public Informational Program on Land Planning and Open Space Protection (organized)
• Review and recommendations on proposed open space development bylaw

Rutland, MA
• Advice to Planning Board, Master Plan Subcommittee, Conservation Commission, and Building Inspector
• Project review (various large residential subdivisions)
• Open Space Design Bylaw (drafted original bylaw, revisions)
• Subdivision Control Regulations (new sections to old version, original and Shutesbury, MA model language and editing of new version)
• Major Home Occupation Bylaw (w/ CMPRC)
• Growth Management Bylaw (Shutesbury, MA model language, editing)
• Sign Bylaw (editing)
• 1997 Community Survey (original)
• Open Space Site Design Studio (supervised Conway School students)
• Demond Pond Lake Association (w/ EQ Section)
• Wetland Protection Bylaw (provided model bylaw)
• Scoping of shared driveway bylaws
• Town Center Mapping (produced USGS and ortho-photos for Rutland EDIC)
• GIS mapping of proposed sewer district (adopted 5/13/06)

Oakham, MA
• Project review and recommendations to Planning Board
• General advice to Planning Board
• Rural Conservation Overlay District Bylaw (model for consideration)
• Subdivision Regulations (model for consideration adapted from Rutland, MA model)

Princeton, MA
• Open Space Development Bylaw (writing and editing)
• Major Home Occupation Bylaw (provided model bylaw)
• Footprint Roads Pilot Program (provided information)

Barre, MA
• Scoping of potential technical assistance projects
• **Subdivision Control Regulations (add environmental standards to existing regulations)**

New Salem, MA
• Consulted with PB regarding roadway standards in subdivision regulations (provided model)

Wendell, MA
• **Assist with Smart Growth Technical Assistance Grant application (to study and develop forest conservation zoning)**

Pelham, MA
• **Assist with Smart Growth Technical Assistance Grant application (to study and develop forest conservation zoning)**

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