5 2005-2014 Management Objectives and Methods

The sections below detail the conversion of the goals specified for each of the Sudbury watershed land management programs into objectives for the ten year management period and methods for achieving these objectives.

5.1 Land Protection

5.1.1 Land Acquisition

Land acquisition has been an important part of protection efforts in the three active water supply watersheds (Quabbin Reservoir, Ware River, and Wachusett Reservoir), with more than 14,000 acres purchased in the past 15 years. Land acquisition has not occurred at Sudbury, however, because of its status as an emergency supply. The Division did not have a legislative vehicle for land acquisition at Sudbury until 1996. The 1996 open space bond provided an allotment of $10 million for the four OWM watersheds, including Sudbury. While the 1997 Watershed Protection Plan for Sudbury does not include a recommendation for land acquisition, purchases may be considered in extreme cases where imminent development may have significant negative impacts to a main tributary or the reservoir.

In 1990, staff from MDC, DEM, and DFW looked at management issues in the upper Sudbury watershed. As part of this effort, MDC staff set priorities for land acquisitions in the Sudbury Reservoir watershed, in case funding became available. At that time, 350 acres were listed in various parcels near the reservoir and the open channel. This review would need to be updated, including an analysis of land sensitivity utilizing new stream, wetland, and land use data, before land could be recommended for acquisition. At this time, however, there is no immediate intent to acquire further property at Sudbury.

5.1.2 Restrictions on Land Disposition

OWM 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. OWM will consider land disposition only under exceptional circumstances for private or municipal uses. Discussions of the transfer of certain lands within the South Basin to other state agencies are ongoing and based on the assumption that these agencies will retain land use practices that are consistent with drinking water supply protection.

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 Environmental Affairs on disposition of Article 97 lands.

5.1.3 Establishment of Forested Riparian Buffers on Private Land

The current Watershed Protection Plan for the Sudbury Reservoir and Framingham Reservoir No.3 watersheds recommends that OWM encourage the establishment of vegetative buffers on private lands along tributaries to the two back-up reservoirs. The vegetative buffers will help reduce pollution (especially sediment and nutrients) flowing from land under commercial, industrial, and residential development. Using 1994 aerial photography, OWM staff estimated there are at least 4,800 acres of riparian areas in these developed land cover/land uses on the Sudbury North Basin watersheds.

From 1996-1997, MDC worked with the Department of Environmental Management, the City of Marlborough, and American Forests, a non-profit environmental organization, to complete an inventory of the forest, grass, and impervious cover on the 1,200 acre Marlborough Brook basin. Using the CityGreen software developed by American Forests, it was estimated that the residential and commercial areas (which made up 66% of the area) averaged 14% tree canopy cover, 24% impervious area, and 61% grass cover.

The program estimated that the tree cover on these developed areas reduced stormwater runoff from a 3 inch rain storm by 711 cubic feet per acre or 600,000 cubic feet for the developed area in the basin. If stormwater detention infrastructure needed to be built to accommodate this added flow, it would cost $2,488 per acre or 2.1 million dollars for the basin. If the above figures were representative of the 4,800 acres of residential/commercial land in the Sudbury Reservoir and Reservoir No.3 watershed, the urban forest on this land would reduce the stormwater from a 3 inch storm by 3.4 million cubic feet, a volume that would cost approximately twelve million dollars in added stormwater infrastructure.

Furthermore, if the sample areas within Marlborough Brook are representative of the 4,800 acres of residential/commercial riparian area in the North Basin, it is estimated that there are over 2,900 acres of grass cover within these areas. As reduction of phosphorus is the highest water quality goal in the Sudbury Watershed Protection Plan (MWRA/MDC, 1997), public education to reduce lawn fertilizer inputs, as proposed in the Protection Plan, could have significant impacts on water quality.

With the goals of improving tributary water quality and reducing urban storm flow, OWM initiated a pilot program at the Sudbury and Foss Reservoir watersheds to encourage the development of vegetative buffers, especially riparian forests, on OWM and private lands near tributaries. This program included technical assistance and funding for tree and shrub planting for private landowners with appropriate streamside locations. The initial pilot program funded $25,000 of tree and shrub planting on approximately 40 parcels of land within the Angelica Brook basin. Planting occurred during the spring of 1998. Based on the success of this pilot, OWM is considering expanding the program to other appropriate sites.

In selecting the 40 parcels of land on Angelica Brook, OWM picked areas that have adequate unused land for a buffer, a relatively small drainage area up gradient, gentle topography, moist soils with shallow groundwater, an absence of vigorous vegetative cover, and little up gradient impervious area. Many of the sites currently have manicured lawn adjacent to the brook. The Angelica Brook area was also selected because it is not sewered, so dense streamside vegetation may help remove excess nutrients from shallow groundwater (Gold, 1994 and Lowrance, 1994). Landowners involved in the program have agreed to water and care for the plantings.

5.1.4 Boundaries

OWM property boundaries are the "front line" of watershed protection, in that they are immediately adjacent to private land on which OWM's watershed protection principles may or may not be followed. Many of OWM's holdings in the Sudbury watersheds are in narrow, scattered strips of land adjacent to development. The protection provided by boundaries is therefore enhanced by regular maintenance to keep them visible, and by immediate identification and resolution of encroachments. Tree and shrub plantings in buffers on OWM land will serve a dual role of water supply protection and protection of OWM boundaries from encroachment from adjacent development.

5.1.4.1 Maintenance

Maintenance of OWM boundaries is a straightforward but daunting task. Before maintaining boundaries, OWM engineering and forestry staff must ascertain their exact location. Establishing boundaries in heavily developed areas for properties that were acquired approximately 100 years ago can be difficult. 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, discussed in greater detail below.

5.1.4.2 Encroachments

Encroachment by abutters onto the Commonwealth's properties has become a significant problem in the Sudbury watersheds. This is due in part to limited ownership, 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 adjacent to, and in some cases in, the Reservoirs). The most significant encroachments are around Reservoirs Nos. 1, 2 and 3.

As resources allow, OWM will begin an inventory of all DWSP lands in the Sudbury system. Staff will identify the types and severity of encroachments, and then work with the property owners to eliminate these encroachments. Most encroachments are discovered by field staff (civil engineers and foresters) while performing routine boundary marking or survey 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 OWM. The best method of 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 OWM staff time. OWM strives whenever possible to resolve encroachments outside of the court.

5.1.5 Policing

This plan focuses on the management and protection of OWM watershed lands. Policing of public access and recreational activities is described in 2002 Sudbury Reservoir Watershed System Public Access Plan Update. Policing is necessary in the following categories to support this plan:

- Patrol and enforcement of public access regulations to prevent violations that may degrade water, forest, wildlife, and cultural resources (for example, all-terrain vehicle use on the area where tree planting occurred at the Marlborough Brook filter beds).
- Patrol and enforcement of regulations regarding illegal activities such as dumping and boundary encroachment that may degrade water, forest, and wildlife resources.

In order to assure that adequate policing of the above activities occurs, OWM staff collaborate with the Massachusetts State Police. The Watershed Ranger program also assists police by locating and reporting violations of OWM rules and regulations and by educating the public regarding these rules. No Rangers are presently assigned full time to the Sudbury watersheds. OWM may investigate the development of Memoranda of Understanding between OWM and local police departments, so that they may enforce certain OWM rules and regulations on OWM Sudbury land.

5.1.6 Fire Protection

OWM is committed to protecting the watershed forest, as well as visitors and neighbors, 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.

Nearly all recent wildfires at Sudbury have been caused by the visiting public and were associated with illegal campfires or improper disposal of smoking materials. No comprehensive records are kept of past fires. The local town fire departments have responsibility for initial suppression and only infrequently notify OWM when assistance is needed.

The following recommendations are necessary to improve the protection of OWM Sudbury lands from wildfires:

- Improve cooperation with local fire departments.
- Improve forest road conditions in areas of poor access and high fire hazard and risk.
- Improve training of OWM staff in fire suppression.
- Draft and implement a fire policy and procedures manual.

In the past ten years, OWM upgraded its fire equipment with the purchase of two 100 gallon slip-on tanks. These are mounted on appropriate existing vehicles during fire season making rapid delivery of water possible down the often narrow and sometimes rough internal Sudbury roads.

5.1.7 Forest Roads

5.1.7.1 General Description

The Sudbury woods road system is essential in order to gain access for key watershed management activities including fire protection, forest management and police patrols. The proper maintenance of woods roads can greatly reduce the deposition of sediment and organic matter into nearby tributaries.

OWM Sudbury watershed lands have a woods road system of nearly 10 miles that provide vehicle access throughout most of the watershed area. Many of these roads date to the pre-reservoir communities that were settled in this area. Some of these were well-constructed, well-drained roads and

have been only partially maintained by OWM. At an average width of ten feet, the 10 miles of Sudbury woods roads cover approximately 12 acres of OWM lands on the Sudbury watersheds.

The amount of maintenance needed on each type of roadway is difficult to predict. The work needed to keep all major roads open throughout the year is largely dependent on the weather. 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.

OWM has identified approximately 3.7 miles of road that will need grading and the addition of bank run and processed gravel, or other work, in the next ten years. Other general road maintenance occurring on a regular basis includes grading, removal of hazardous roadside trees, roadside mowing (which facilitates drainage and keeps roads open), and the processing and spreading of gravel as needed to maintain access or for specific land management activities.

5.1.7.2 Best Management Practices for Road Maintenance Activities

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 OWM properties is accomplished by OWM staff and equipment.

To accomplish these objectives OWM crews use various mitigating procedures to protect stream water quality during routine maintenance activities. These procedures are outlined below. It should be noted that specific sites may require special systems not described here, such as the use of geotextile, 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.

- **Detention and Retention Basins:** These basins will be installed where needed during road reconstruction activities to reduce the velocity of stormwater and increase infiltration.

- **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. OWM 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.

It is OWM's intention to limit 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, OWM 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.

5.1.7.3 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 must be constructed, or new sources of gravel developed. 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:

- Development of a plan showing the location to be affected, time sequence of removals and procedures to be employed,
- Consultation with OWM 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.

5.1.7.4 Considering 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. OWM constantly deals with plugging of road culverts by beaver. In some situations, OWM 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, OWM 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. OWM 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, OWM will incorporate beaver considerations in choosing stream crossing methods. In addition to evaluating watershed area, road classification, and stream size and gradient, OWM 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.

5.1.7.5 Management Guidelines for Beaver at Road Stream Crossings

OWM 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:

- Where feasible and applicable, replace existing smaller culvert pipes with larger, oversized pipes.
- When possible, box or pipe-arch culverts should be used with a minimum inlet opening area of 18 ft^2. Smaller sizes are easily plugged.
- When sizing the culvert, it is important that the width of the culvert 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.
- When installing culverts, avoid creating a depression or pond at the inlet as these are attractive to beaver.
- Installing multiple smaller pipes at a site instead of a larger pipe is not a workable alternative. Smaller pipes are much more likely to be plugged.
- In situations where beaver have a history of plugging even large culverts, other management options may be needed (see section 5.4.3).

5.1.8 Areas with Special Management Restrictions

The recognition of a category of land on which management is restricted was first proposed in the 1972 Quabbin Reservoir Watershed Management Plan. That plan recognized those areas as "Protection Areas" where management would not be allowed due to potentially negative water quality or other impacts. Sites falling into this category included islands, rock quarries, mill sites and exceptional forests among others. This idea was further refined in subsequent Quabbin plans and that tradition and concept is carried forward into this land management plan for the Sudbury reservoirs.

Areas under special management restrictions fall into two general categories:

- Areas where regular forest management is impractical or may result in unacceptable impacts.
- Areas with uncommon, rare or potentially rare resources.

The first category includes areas that are commonly occurring but are also fragile, sensitive or impractical such as forested wetlands, marshes, bogs, vernal pools or steep slopes greater than 30%. The second category includes areas such as uncommon forest types, locations of rare, endangered or threatened species of plant or animal, and historic or prehistoric sites.

A new addition to the second category is areas known as "Primitive Woodlands." Henry David Thoreau discussed the concept of primitive woodlands as part of an overall forest classification system. He adapted this system from a land classification system put forth by the English landscape architect William Gilpin. Thoreau defined primitive woodlands as those that have always been forested, even thought they may have been cut one or more times in the past. The critical characteristic is that these woodlots were never used for agricultural purposes and that they therefore have always had a forest floor (Foster, 1999). Many questions need to be answered before specific management recommendations can be made. What ecological value do primitive woodlands have? Does the presence of these areas add to the biological diversity of the area? How many acres and where are the primitive woodlands on OWM lands? Initial investigations looking at 1830 survey plans of each town indicate that there is the potential for a significant acreage of primitive woodlands. These plans show the areas within each town that were still forested at the peak of agricultural clearing. However, how many of these areas that were forested in 1830 were subsequently cleared? OWM hopes to further investigate this intriguing concept.

To date, OWM has identified 1,026 acres of land in the Sudbury watersheds that will be classified as "Areas with Special Management Restrictions" (Table 9). These areas include the 386 acres of Big Crane and Little Crane swamps plus 119 acres of other wetlands, 116 acres of islands, and 405 acres of riparian zones. In addition, there are many small areas not yet tallied, representing sensitive resources and buffers around historic and rare wildlife habitat areas such as vernal ponds, as well as potential areas of "primitive woodlands." OWM also limits management on areas considered to be sheltered from the exposures that historically have been damaged by catastrophic hurricanes.

TABLE 10: AREAS WITH SPECIAL MANAGEMENT RESTRICTIONS

Type of Area	Size	Restrictions
Islands	116 acres	No management
Wetlands	505 acres	No management except limited beaver control (see beaver policy)
Riparian zones adjacent to tributaries and the Reservoir shore	405 acres	All areas subject to filter strip restrictions of FCPA (Ch. 132); some also limited to non-harvest silviculture
Disturbance-sheltered areas	Undetermined	Relatively low intensity management
Areas of historic, cultural or natural significance	Undetermined	Varies from no management to selective restoration and management
Primitive woodlands	Undetermined	Restrictions yet to be determined (see text 5.1.8 above)

LARGE VERNAL POOL: BREEDING HABITAT FOR AMPHIBIANS

5.2 Forest Management

5.2.1 Description of Forest Management Approach for Ten Years (2005-2014)

5.2.1.1 Objectives for Sudbury Forest Management

OWM has determined that the watershed protection function will be served best by a forest in which the majority of acreage is diverse in age, species, and vertical structure, is actively accumulating biomass, and is continuously reproducing. Establishing and maintaining this "watershed protection" forest can provide benefits throughout the watershed, but to the extent that reservoir shoreline and streamside areas provide the critical final buffer for capturing nutrients and sediments originating on developed lands in the Sudbury watersheds, a dense, vigorous *riparian* forest is of particular importance.

The Sudbury watershed forest is chronically subjected to natural disturbances, including wind, fire, insects, diseases, animals, and floods. In addition, the majority of the current Sudbury forest consists of 75 to 90 year old even-aged stands often without well-established regeneration and usually without graduated vertical structure. Without a graduated vertical structure, the ability of this forest to continuously maintain its protective function following large and/or a series of small natural disturbances may be impaired.

As the principal value of the OWM lands within the Sudbury watershed forests is as a buffer along reservoir shorelines and tributary banks, the most important objective of this management period is to maintain this forest buffer and its function in protecting water quality. On areas away from water courses, the objective of management over the next ten years is to foster regeneration where it is missing and to encourage existing regeneration that is appropriate to the site. On all sites, the objective over the long term is to enhance age and species diversity on each site, while keeping the majority of the forest cover in a state of active growth (to assist in water and nutrient regulation), through a range of silvicultural practices.

A silvicultural system is defined as, "…a planned program of silvicultural treatments during the whole life of the stand" (Smith, 1986). The name of the system is commonly derived from the name of the reproduction method that is used to regenerate the stand. The silvicultural system that will be employed throughout the vast majority of the Sudbury forest in order to create three distinct age classes is a variation of an uneven-aged system. The silvicultural method that perhaps best describes the regeneration plan for the Sudbury forest is group-selection or uneven-aged with patch cutting as suggested by Marquis (1991). However, the tendency to pigeonhole a complicated and highly variable process into a pre-defined term can unnecessarily restrict the wide variety of techniques available to forest managers. "Formulation of a silvicultural system should start with analysis of the natural and socioeconomic factors of the situation. A solution is then devised…When the important act of inventing the solution has proceeded far enough, the less important step of attaching a name to it can be taken." (Smith, 1996)

Over the next 30 years, 30%, or about 400 acres of the managed forest at Sudbury will be converted to a new age-class. For this age class to be evenly distributed throughout DCR land and evenly spaced through time, 13 acres must be regenerated each year. Therefore, approximately 40 acres will be treated annually (one third of which is regenerated).

5.2.1.2 The Role of Natural Disturbance

Natural disturbances occur at virtually all scales of time and area. The infestation of individual trees by the *Nectria* fungus, the perpetual browsing of regeneration by deer, and a 500 acre, lightening-caused forest fire are all natural disturbances. These disturbances, though "natural," can compromise the ability of the forest to protect water quality. It is the goal of OWM to insure the supply of high quality drinking water for both the short and long term. The management of the Sudbury forest must be planned to mitigate negative impacts resulting from natural disturbances on many scales.

WACHUSETT MICROBURST 1989

The most significant disturbance that affects the forests of Massachusetts is hurricanes. From meteorological records and forest reconstruction it has been estimated that hurricanes strike southern and central New England every 20-40 years, while catastrophic storms like those of 1635, 1788, 1815 and 1938 occur approximately every 100-150 years (Foster, 1988). Catastrophic hurricanes have the ability to disturb a significant portion of the forest, changing species composition and age distributions suddenly. However, there are variables that affect the extent to which a forest is impacted by various windstorms and some of these are under the forester's control. A study of the Hurricane of 1938 at Harvard Forest in Petersham, MA (Foster and Boose, 1992) showed that conifers are more susceptible to windthrow than hardwoods and tall trees are more susceptible than short trees. These two factors in combination with the slope and aspect of any given site are significant determinants of wind damage. In the Harvard study, conifers greater than 34 feet tall and hardwoods greater than 74 feet tall on nearly level sites (<5 degrees) or windward oriented slopes (S, SE, E) were severely damaged (>75% of all trees were damaged); there was intermediate damage (50-75% of all trees were damaged) on mild leeward slopes (5-10 degrees, N, NW, W) or intermediate orientation (NE, SW; >5 degrees). Hardwoods greater than 64 feet tall on these same exposures were damaged 51-75% and 25-50% respectively.

The structure of an uneven-aged forest, with three age classes well distributed across the landscape, is well designed to both resist and recover from the impacts of windstorms. Resistance should be improved when much of the forest is shorter than the critical height categories according to the Harvard model and resilience is improved when there are enough young trees in place to reoccupy the site should the overstory be destroyed. This structure should translate to less risk to water quality from nutrient or sediment flux in the event of a major windstorm. Fewer trees blown over means fewer trees needing to be salvaged and reduced fire hazard, and therefore a lower risk of subsequent nutrient losses to tributaries and the reservoir.

One of the most significant impacts to the riparian zone through history has been catastrophic flooding. Several studies show that the scouring that occurs in large infrequent storms contributes significant amounts of annual outputs of sediments and nutrients (Patric, 1980). One of the effects of urbanization on a watershed is to greatly increase the size and frequency of flood flows. As OWM forest lands are located downstream of many urbanized areas, they can help protect the reservoirs from the effects of floods by settling and absorbing sediment before it reaches the reservoir. By maintaining a diverse and actively growing forest within the riparian zone, these values can be enhanced (Welsch, 1991).

5.2.1.3 Forest Insects and Diseases

Damaging insects and disease-causing organisms are as normal and natural a part of the forest ecosystem as the trees themselves. To view these organisms as nothing more than destructive agents whose absence would only benefit forest health is to misunderstand their ecological role. They are vital components of biological diversity and play key roles in nutrient cycling, decomposition and predator-prey relationships. The impact of an infestation or disease outbreak becomes a concern when it conflicts with management objectives. A homeowner, whose specimen birch tree is infested by the bronze birch borer, is justified in viewing the situation as serious and worthy of immediate action. The death of this tree would conflict with the objective of an attractive yard. A single infested tree in the middle of the forest is not a concern where the objective is to have a vigorous, functioning forest ecosystem.

In the Sudbury forest, insects and disease are a major problem only when their impacts conflict with the OWM's objective of creating and maintaining a watershed protection forest. For the most part, this means that only large-scale outbreaks that threaten to alter tree species diversity or forest structure fall into this category. Chestnut blight was such a disease. It was first discovered in the Sudbury forest in 1911 and had already spread to chestnut trees in all towns of the watershed. 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, seldom reaching the size of a small tree before again being infected, dying back to the ground and perhaps putting out new sprouts.

The gypsy moth is another example of a serious pest. It was first found in the Sudbury forest in 1909. A great deal of effort was spent in trying to control the inexorable spread of this insect. Every winter, all egg masses that could be found were painted with creosote. The Sudbury Reservoir Annual Report for 1916 states, "Some time was spent scouting for gypsy moth egg clusters and painting them with creosote, and 120,200 clusters were painted at Sudbury Reservoir, 67,400 at the Framingham reservoirs…at a cost of $864.07." This work continued at least until 1947 when the last annual report was written. Epidemics of this insect can result in significant mortality of a wide range of tree species both in the overstory and understory resulting in alterations to forest structure, composition and health.

Both the fungus that causes chestnut blight (*Cryphonectria parasitica*) and the gypsy moth (*Lymantria dispar*) are introduced organisms that came to the Sudbury forest without their co-evolved complement of predators and parasites; a recipe for the development of an unhealthy ecological condition. Other examples that have in the past or currently affected the Sudbury forest include Dutch elm disease, beech bark disease, and white pine blister rust. Native species generally remain in balance with their predators except when cultural effects (past land use or deliberate forest management) create unusual conditions. Some examples are establishing species that are unsuited to the site, deliberately creating single species stands (i.e., plantations), and growing forests on soils that are nutrient depleted from a long history of farming practices.

The next significant threat to the Sudbury forest is the hemlock woolly adelgid (*Aldeges tsugae*), a small aphid like insect native to Asia, which was first seen in the eastern U.S. in Virginia in 1955 and has been moving up the east coast since then. It feeds on hemlock at the base of the needles, removing nutrients and secreting a toxic substance in its saliva. The most recent research and observations indicate that the amount of hemlock in the forests of Massachusetts may be significantly reduced by this insect over the next decade or more. Hemlock comprises less than 1% of the stocking of the Sudbury forest and no extraordinary measures will be taken to salvage infested hemlock on upland sites. However, sites deemed more critical to water quality will be considered for salvage operations or non-harvest treatments within the constraints of the current OWM Hemlock Woolly Adelgid Management Policy (OWM 2004).

5.2.1.4 Species/Site Suitability

Although some Sudbury forest stands are established on sites suited to their long-term growth and development, many are not. The current Sudbury forest originates primarily from plantation establishment from 1907 to 1947, with the majority of the approximately 1.75 million seedlings planted from 1913 to 1921. As many of the pines were planted on rich soils more suited to native hardwood species, some plantations are unstable and lack vigor. The most pronounced examples are red and white pine plantations on poorly-drained soils, which are prone to various diseases. These sites would support a diversity of long-lived, low-maintenance hardwoods if the pine canopy were opened to allow light to the forest floor. Therefore, it is one of the objectives of forest management at Sudbury to identify stable soil/species combinations and to encourage their development through silvicultural operations.

5.2.1.5 Analysis of Sudbury Forest Regeneration

Regeneration is the key to the creation of a diverse and stable forest. Procuring an adequate level of regeneration beneath the Sudbury forest overstory depends upon seed sources, appropriate seedbed conditions for germination and initial establishment, and proper conditions for development of the established seedlings. Each species of trees has a specific range of conditions that must be met for the reproduction of that species to occur. Evolution through natural selection has insured that all possible site conditions are suitable for some species of plant from lichens growing on bare rock to red maples living in swamps. It is the job of the OWM forester through silvicultural operations to encourage, through management, the necessary conditions for the regeneration of the species best suited to the site.

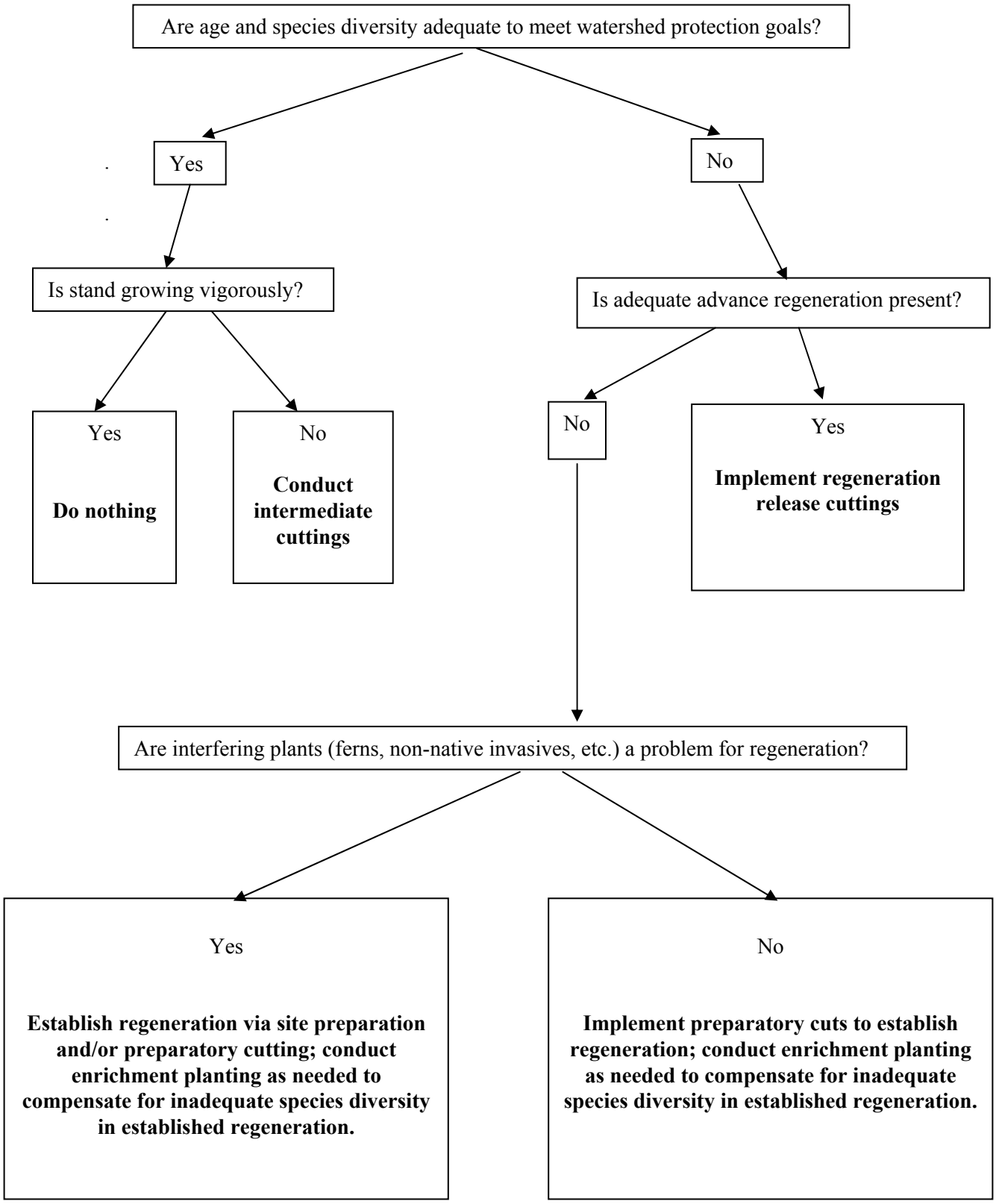
The current condition of regeneration on the Sudbury watersheds was described in Section 2.4.1.3. The Division defined “adequate regeneration in its 1991 Quabbin Deer Impact Management Plan (MDC, 1991), in order to specify what was meant by "success" in efforts to recover a Quabbin understory. Adequate regeneration was defined as the establishment of at least 2,000 stems per acre of seedlings/saplings greater than 4.5 feet in height with a diverse species composition well-suited to prosper on the range of sites present across the forest. While natural disturbances can positively affect local regeneration conditions, the effects are unpredictable. Carefully planned silviculture will encourage persistent regeneration throughout the managed forest and provide better control over species composition. This controlled regeneration response will increase the resistance of the watershed forest to major disturbances such as catastrophic hurricanes and the resilience of this protection forest in recovering from these disturbances.

5.2.1.6 Silvicultural Practices

Figure 4 outlines the general decision-making process OWM Foresters follow to determine the appropriate silviculture for any area. At its most basic, the process can be simplified to the following:

- Where regeneration is lacking, establish it.
- Where regeneration is adequate, released it.
- Encourage species appropriate to the site.
- Cut the poorest quality trees first and leave the best.

FIGURE 4: SILVICULTURAL DECISION-MAKING PROCESS



Establishment of Regeneration: Preparatory Cutting and Planting

There are at least three factors to consider when determining the adequacy of existing regeneration at a site: the species composition/site suitability, the number of seedlings/saplings, and the spatial arrangement. A high number of seedlings well distributed but of a species poorly suited to the site is considered inadequate. Conversely, a patchy distribution of a variety of species well suited to the site may be adequate if it occupies enough of the area to warrant release as a new age class. In the 1991 Quabbin Reservation Deer Impact Management Plan (MDC, 1991), an exhaustive literature review and a survey of regeneration in "off-Reservation" lands at the Quabbin were performed in order to determine what "success" meant regarding the level of regeneration following deer population control efforts. Adequate regeneration was defined as the establishment of at least 2,000 stems per acre of seedlings/saplings greater than 4.5 feet in height of a diverse species distribution. Spatial arrangement, the distribution of regeneration across the forest, is an additional objective of regeneration adequacy.

On sites where the level of regeneration is considered inadequate, preparatory cuttings will be prescribed. These are designed to open the canopy sufficiently to allow increased light and heat levels at the forest floor thereby stimulating seed germination and seedling development. At the same time, the species composition of the overstory, and therefore the makeup of the seed sources, can be adjusted, disturbing the leaf litter can enhance the seedbed, and competing vegetation can be reduced.

In situations where a desired species is absent from the overstory and therefore a seed source is unavailable, planting will be considered. The most common examples of this situation are dry site mixed oak stands with no white pine component in the overstory. The only practical method to establish white pine in these stands is through planting.

Release of Regeneration

Once adequate regeneration is in place, it will be released systematically to give it light and space to grow. This is accomplished by harvesting a portion of the overstory from designated stands. The cutting cycle (the period between harvests) for any given area will average 20 to as long as 30 years, depending on the site. Most areas will be treated using a variation of the selection method as previously described. Trees will be removed either singly or more often in groups and patches ranging from ¼ acre to 2 acres in size, with an average of about 1 acre. This range in opening size allows for the successful regeneration of a wide diversity of species due to varying tolerances of shade. It is anticipated that openings larger than one acre will become increasingly rare as the forest is brought into a more balanced distribution of ages, sizes, and species than currently exists.

Occasionally, there is the need to take a more wholesale approach to the conversion of stands comprised of species poorly suited to the site or unstable stands of damaged, low-vigor trees. Overstory removals larger than 2 acres are considered an option for the treatment of some plantations on the Sudbury watersheds, generally including those comprised of red or white pine and Norway or white spruce. Some of these plantations were never thinned and consequently the trees are tightly spaced with short, narrow crowns. These stands are poor candidates for small openings or partial overstory removal due to poor form and inadequate wind-firmness of the residual trees. The most practical method for regenerating these stands is the removal of larger blocks of overstory trees following the establishment of regeneration. Regeneration may be established in these stands either through the very careful application of a preparatory operation (the creation of strips within the plantation or overstory removal immediately adjacent to the plantation) or through planting.

In order that an adequate accounting be kept and to insure that each regeneration cut leads to the desired result, the acreage of the area that is released to a new age class for each silvicultural operation

will be recorded, usually through precise mapping of openings using GIS mapping software. In this way, the long-term impacts of management will be assessed as well as the immediate impact on the distribution of age classes within the stand, sub-basin and forest. OWM intends to contract a photographic fly-over of OWM property mid-way through each ten-year management plan period. This will greatly enhance the ability to document and monitor the progress of this gradual conversion of the forest. Figure 4 depicts the generalized, long-term silvicultural strategy for converting the current even-aged forest to one composed of balanced distributions of three age classes.

Intermediate Cuttings

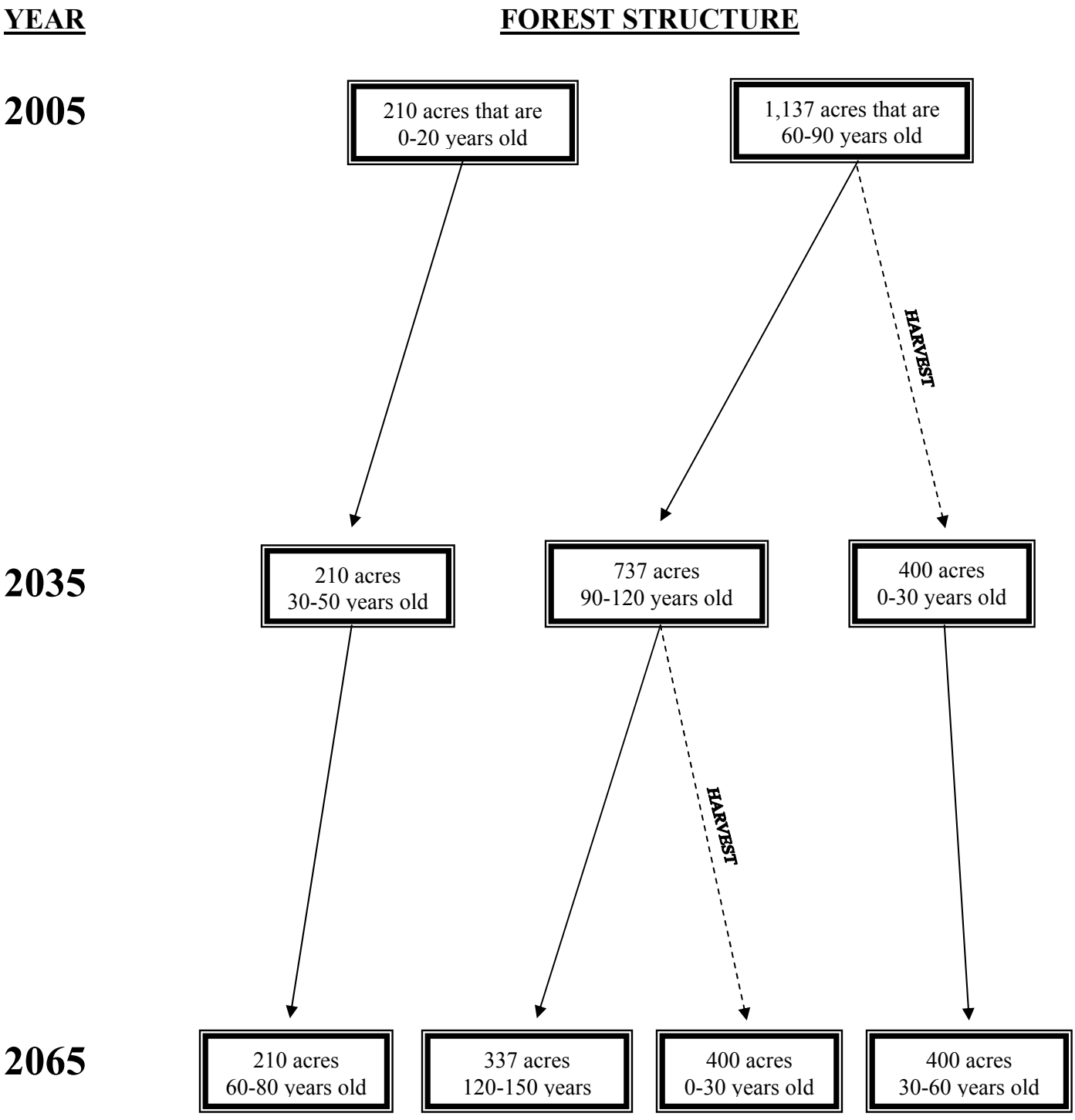
Intermediate cuttings are performed on stands prior to maturity. They are designated as "thinnings" when the objective is to remove trees of low vigor thereby decreasing competition within the stand and increasing the vigor and growth rate of the remaining trees. "Improvement" operations are designed 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.

In the Sudbury forest, intermediate cuttings are rarely performed independent of other treatments, as there are very few purely pole-sized stands on OWM property needing only thinnings. Most intermediate operations are performed simultaneously with preparatory and regeneration cuts, particularly when stands are being treated for the first time without the benefit of prior management.

Riparian Zone Management

The most common riparian zone management strategy applied by land managers 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 not the cutting of trees but the soil impacts associated with harvesting equipment that is associated with these effects. OWM recognizes these zones as the final, and most critical, opportunity to slow or capture nutrients and sediments released by a variety of natural and man-caused events on the watersheds. OWM therefore works to bring positive changes without negative impacts. For example, trees may be felled to bring light to the understory but not removed, or trees may be winched from the site without driving equipment into the riparian zone.

FIGURE 5: CHANGES IN SUDBURY FOREST AGE STRUCTURE VIA SILVICULTURE, 2005-2065



While urbanization increases flood flows and the concentration of a number of pollutants in stormwater, forested buffers help to filter these pollutants before they reach streams. Depending upon the size of the forested area, these buffers may also reduce the magnitude of flood flows (Anacostia Restoration Team 1992, Neville pers comm., 1996, Lowrance, 1994, Schueler, 1987, USDA Forest Service, 1991, and U.S. EPA, 1993). Forested buffers also have the benefit of discouraging geese from grazing and loafing on the reservoir shoreline. While most OWM riparian lands are already forested, additional protection can be gained by enhancing the structure and composition of riparian forests and by reducing shoreline and streamside mowing practices.

The preferred vegetative structure of riparian zones is an actively growing, diverse, self-perpetuating, and disturbance-resistant forest cover. Maintaining this forest structure throughout the variety of disturbances that impact all New England forests may be best accomplished through carefully planned and implemented management. To some degree, being located within the bottom of stream and river valleys shelters riparian forests from wind damage. However, as these forests mature, and especially where they are in the path of prevailing storms, they become vulnerable to sudden and dramatic damage. When this damage 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 the loss of forest cover and heavy additions of organic matter to the stream when groups of trees fall directly into the stream course.

As is true for maintaining the watershed forest in general, the most important resistance to build into these forests 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 forests following disturbances.

Riparian forests that are simply left alone will establish regeneration as the overstory begins to age and decline in vigor. However, where full crown closure is maintained for long periods of time, 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, OWM intends to systematically "condition" certain vulnerable riparian forests to be better able to fulfill their critical buffering functions throughout significant disturbances. Specific management strategies, and the types of riparian zones to which they will be applied:

- Standard silvicultural removals will occur within the managed forest where soils and cutting practices allow.
- Directional felling of small groups and individual trees, without removal, will be done to bring light to the understory where soils prevent equipment of any size. Trees will be felled perpendicular to prevailing slopes and cut into sections so that the trunk comes in contact with the ground to enhance the sediment trapping capabilities of the riparian zone. Felling will not be done into streams. It is felt that natural fall due to individual tree death (as opposed to catastrophic events) will add sufficient material in streams to create beneficial debris dams.
- Planting will occur in areas where seed source is limited, where herbaceous competition is significant, where protective ground cover is currently lacking (e.g., under dense plantations), and where aesthetics is a concern (e.g., near residences or high use areas). This practice may include planting with "tree tubes" sufficiently tall to bring seedlings above herbaceous cover and reduce deer damage. Non-harvest fellings may also be included in order to maintain light levels sufficient to support understory growth.

This technique will initially consist chiefly of directional fellings and tree plantings. The areas chosen to apply this approach include:

- Areas where an important buffer or riparian area is involved.
- An area that is exposed to significant disturbance, such as from future hurricanes.
- An area that would benefit from planting and tubing to help establish regeneration.

Salvage Policy

Salvage cutting has increased in recent decades on OWM properties due to the advancing average age of the watershed forests, the steady arrival of new insect pests, and storm events such as the microburst of 1989. In addition to (or shortly following) insect and disease damage, this older forest is more susceptible to windthrow (especially of trees with weakened root structures), and ice and snow damage. Salvage activities are not planned, but are important components of watershed maintenance when the disturbance damages large areas of forest, or greatly increases the threat of additional damage. Removals of dead or dying trees from damaged forests can lower fire hazard (e.g., in hemlock defoliated by hemlock looper or woolly adelgid), allow the salvaging of timber value, and strengthen the resistance of surviving trees (e.g., by removing trees weakened by gypsy moth to shift site resources to adjacent, healthier trees). OWM staff is aware of the importance of the steady addition of large woody debris to the forest ecosystem. However, the volume of dead and dying wood that is eventually salvaged is a small fraction of the total mortality in any given period of time. Therefore, ecosystem functions will continue to be met while other short-term concerns are addressed.

Where large areas are involved, salvage activities may preempt planned activities described in this plan. Following the microburst tornado that struck the Wachusett and Sudbury watersheds in 1989 (and damaged 300 acres of OWM forest in less than 20 minutes), there was strong public pressure to "clean up the mess." The close proximity of these watershed forests to residential developments may increase the priority for salvage following disturbances, to improve aesthetics and reduce both perceived and actual fire danger. In addition to public pressure for a rapid response, there are often other time pressures driving salvage operations. For example, when white pine is damaged during the warm months of the year, its wood loses value rapidly due to fungal invasions that cause discoloration (e.g., "blue-stain"). Wood-boring insects also invade damaged timber rapidly during warmer months and can greatly reduce value. Where roads are blocked by disturbances in adjacent forests, there is also an obvious need to conduct salvage rapidly in order to restore access, which is critical for fire control and emergency response. In situations that involve these time pressures, review and timber harvest permit procedures may be streamlined when an operation is deemed to be salvage and conditions warrant rapid action.

5.2.1.7 Summary of Planned Silvicultural Activities

Table 11 presents OWM plans for silvicultural activities from 2005-2014.

TABLE 11: PLANNED SILVICULTURAL ACTIVITY, 2005-2014

Operation	Estimated Amount
Pine Plantation Intermediate and Regeneration Cuttings	300 acres
Non-Plantation Intermediate Cuttings	10 acres
Non-Plantation Preparatory and Regeneration Cuttings	100 acres
Tree Planting	3,000 seedlings on 30 acres

5.2.1.8 Reducing Shoreline and Streamside Mowing Practices

The impact of the shoreline areas upon reservoir water quality is significant at Sudbury Reservoir. The Sudbury Reservoir has a relatively small drainage basin compared to the surface area of the reservoir. The drainage area/surface area ratio for Sudbury Reservoir is 9.8 compared to 18.7 for the Wachusett Reservoir (CDM, 1995). Therefore the land draining directly to the reservoir and not into a stream channel first is relatively large (more than 15% of the watershed as measured in a recent study (Comprehensive Environmental, 1997). The Sudbury Reservoir also has a very dendritic shoreline, which magnifies the impact of these lands. This feature means that a relatively large percentage of the watershed is in proximity to the reservoir (4,974 acres or 28% of the watershed is within 400 feet of the reservoir).

The management of the shoreline buffer zone is, therefore, a very important part of the overall protection of the water quality of the reservoir. In the past, OWM has actively cut vegetation along many sections of the reservoir shoreline and some tributaries. The MWRA, which has jurisdiction over the "open channel" that flows from the terminus of the Sudbury Aqueduct in Northborough to the Sudbury Reservoir, has also regularly cut woody vegetation along this waterway. The reason for past vegetation cutting was to reduce the amount of leaf litter in the reservoir. Leaf litter adds organic material and color to the reservoir. This is the same reason why pine plantations and arborvitae hedges were often planted along reservoir shorelines in the region. However, for larger reservoirs, such as the Sudbury, which do not have an arborvitae hedge (unlike the Wachusett Reservoir), it is felt that the following benefits of a stable and actively growing forest outweigh the potential problems caused by leaf litter:

- Stabilization of shoreline soils with differential rooting patterns and depths.
- Reduced shoreline usage by Canada geese.
- Increased infiltration capacity of soils.
- Protection of erodible mineral soil by thick layer of organic material.
- Absorption of excess nutrients.
- Detention of sediment and associated pollutants.
- Reduction in raindrop erosion potential via interception by forest canopy.
- Reduction of amount of precipitation reaching the ground through interception by vegetation.
- Reduction of flood peaks.
- Near elimination of overland flow.

(Dyrness, 1965, Hewlett and Nutter, 1969, Lull and Reinhart, 1972, Patric, 1978, Robinson et al., 1979, Schueler, 1987, Welsch, 1991, and U.S. EPA, 1993).

For these reasons, the Division implemented a program of reduced shoreline mowing and cutting in the mid-1990s. The only areas where regular cutting will continue will be on and adjacent to dams and other water supply facilities and buildings and access roads. OWM will coordinate with MWRA staff for a similar program for buffer areas along the Open Channel with the same exceptions.

5.2.1.9 Silviculture by Forest Type

The principal forest types found in the Sudbury watershed forests are described below, with a brief description of silvicultural approaches applicable to the type within the context of watershed management. Due to the relatively small acreage of OWM-controlled land in the Sudbury watersheds, it has been possible to map the forest types in extremely fine detail. For the purposes of this section, some

of the types have been grouped together. For example, there is a total of five acres of the northern hardwood type. This represents less than one half of a percent of the total forested land. Rather than describe this type separately, it has been grouped with the mixed hardwoods type to which it is most similar. The composition of the managed forest on OWM land at Sudbury is summarized in the table below:

TABLE 12: COMPOSITION OF MANAGED FOREST IN OWM PROPERTIES AT SUDBURY

Forest Type	Acres
White Pine	327
Mixed Hardwood/Red Maple	313
White Pine/Oak/Hardwoods	299
Oak	249
Mixed Pine	59
Red Pine	55
Spruce	31
TOTAL	1,333

White Pine Type

White pine covers 327 acres or about 24% of the management zone. The vast majority of this type was established by the planting of nearly 900,000 seedlings from 1907 to 1947. The bulk of the planting took place from 1913 to 1921 around the Sudbury Reservoir and Reservoir #3 which makes these plantations 80 to 90 years old. The Walnut Hill and Crane Swamp plantations are 60 to 80 years old having been established from 1924 to 1943. These stands are nearly pure white pine with occasional small inclusions of various hardwoods.

Most of the white pine is growing on sites that are far better suited to growing hardwood species or at least a mixture of hardwoods and pine. In fact, many of these plantations currently possess an understory of excellent hardwood regeneration. The soils in these situations are generally deep and well to moderately well-drained tills. The problem with pines growing on hardwood sites is that they are more susceptible to wind and ice damage and disease. In addition, a stand comprised of a single species is inconsistent with OWM's goal of a diverse, multi-layer watershed protection forest. The long range goal is to convert these pure stands to either a mixture of white pine and hardwoods or to all hardwoods. This will be accomplished through a combination of preparatory and regeneration cuts utilizing group selection and shelterwood, depending upon specific site conditions.

Thinnings, along with an occasional sanitation cut to remove diseased plantations, will continue into the foreseeable future when feasible. However, the majority of pine plantations are not in a suitable condition for thinning. These trees were planted at a 6 by 6 foot spacing which necessitates a series of thinnings as the stand grows. These thinnings did not occur. As a result, these pine plantations are greatly over-crowded with very small live crowns perched atop spindly 70 to 100 foot tall stems. Such trees are unable to utilize the increase in light, moisture and nutrients that the removal of their competitors provides. These stands are presently highly susceptible to wind and ice damage and thinning would only serve to increase the likelihood of such damage.

Most silvicultural activities during the next 10 years will therefore be overstory removals with the objective of releasing regeneration and other younger age classes when adequately present or to encourage the establishment of regeneration when such levels are not adequate. The intensiveness of the removal will be directly related to the level and nature of the regeneration. Where the regeneration is of

an adequate amount and of suitable species, white pine overstory removal will be more aggressive and intensive. Where the regeneration is not adequate, either due to insufficient amounts or an unsuitable mix of species, the removal of the overstory will occur more gradually over time. The history of Sudbury pine plantation management is summarized below:

TABLE 13: SUDBURY PLANTATION HISTORY

Practice/Condition	Acres
Original plantings	640
Plantings that survived to 1988	520
Harvesting/thinning 1980s	215
Harvesting/thinning 1990s	122
Harvesting/thinnings since 2000	99
Total harvests	436
Salvage cutting	36
Current plantations	454

Mixed Hardwood and Red Maple Types

Mixed hardwood and red maple types cover 313 acres or about 23% of the management zone. About 45 acres of this type is the sapling sized regeneration growing in the openings made by OWM in the extensive pine plantation on Walnut Hill in 1988. Pin and black cherry, red maple, aspen and white pine are the dominant species. Enrichment planting took place in 1995 when 1,500 red oak and sugar maple were planted on a portion of Walnut Hill that blew down and was then salvaged in 1989. Some areas now have a significant component of oaks due in small part to the planting but primarily to natural regeneration.

The balance of this type is pole to sawlog sized and is dominated by red maple and white ash. Black cherry, red and white oak, sugar maple, hickory, elm, aspen, and white pine are also found in this type. Moderately to poorly drained soils tend to support this mix of species. The 1911 cover type map describes these sites as generally "grass," "pasture growing to brush," or a mixture of early successional species such as "birch, poplar, willow." The ash and maple therefore are no more than about 85 years old.

Regeneration is often lacking beneath these stands due to a thick and aggressive shrub understory. Honeysuckle is the most prevalent problem. False spirea (Sorbaria sorbifolia) has created a similar situation in a few locations. Silviculture in these areas will seek to establish a new age class of suitable species. This interfering shrub layer will be physically controlled by logging equipment during partial overstory removal operations. A mix of primarily long-lived hardwood species will be sought.

White Pine/Oak/Hardwoods Type

The white pine/oak/hardwood type covers 299 acres or about 22% of the management zone. Most of this type originated as white pine plantations that gradually gave way to hardwood intrusions. Insects, disease, fire, and storms all contributed to breaking up the initially pure pine overstory. The mix of hardwood species that now share these stands with the pine is largely determined by the site. Red maple, ash, and elm moved into the wetter, more poorly drained lowland sites. Oaks and hickories now grow with pine on drier, better drained soils. Regeneration is generally very good with a wide range of species represented.

The goal of silviculture is to release this young age class by partial removals of the overstory. The size of these openings will primarily be determined by the regeneration present. Openings ranging in size from 1/4 to 2 acres will generally be used. Larger removals will be considered where adequate regeneration is present beneath a poor quality overstory that is unsuited to the site. An example is a predominantly pine overstory on a poorly drained site with adequate red maple and ash regeneration.

Oak Type

The oak type occupies 249 acres or about 19% of the management zone. The majority of this type is found in the Pine Hill Compartment. A vegetation type map created in 1911 describes the areas that are currently oak forest as "chestnut, oak and maple," "large chestnut and oak," or "sproutland, scrub oak and other wood." The chestnut blight, first detected at the Sudbury Reservoir in 1911, effectively eliminated the American chestnut from the forest. Today, chestnut exists as a minor understory shrub. Red, black, scarlet, and white oak are the dominant species. Red maple, hickory, white ash, black birch, and white pine are minor components.

The more upland, well drained sites are dominated by black, scarlet, and white oak. Gypsy moth infestations have been the most severe in these stands. It will be the goal of silviculture to encourage the establishment of other species into these generally low vigor stands. White pine is the best candidate as it competes and grows well on these dry upland sites. Natural regeneration will be sought where there are suitable white pine seed sources. Otherwise, planting of pine seedlings will occur. Regardless of the source of the regeneration, openings will be created in the oak overstory to provide suitable conditions for white pine development.

Red oak is the dominant species where soil moisture is less limiting. Chestnut blight and the superior ability of red oak to sprout following fire or grazing are why there are nearly pure stands of red oak today. The long lived and high vigor red oak will be the favored species on these sites. However, a transition to a wider variety of species is inevitable and will be encouraged to diversify the species composition.

Mixed Pine Type

The mixed pine type covers 59 acres or about 5% of the management zone. This type includes mixtures of species that are unusual. Scotch pine was planted in 1917 in Compartment 3, the Route 85 and Acre Bridge Road area. Much of this Scotch pine was removed in an operation in 2000 that released the excellent sugar maple dominated understory. Since then, white pine and a mix of hardwood species have infiltrated the formerly pure plantations. At Walnut Hill and Crane Swamp, red pine and white pine were planted together in 1928. These stands have maintained a nearly pure pine overstory. This type occupies soils ranging from excessively drained outwash to moderately well-drained till.

Many of these stands have abundant and diverse regeneration. Silvicultural operations will begin the process of removing the overstory in stages. The resulting forest will consist of a diversity of species and size classes. Scotch pine will not be encouraged. This introduced species is typically of poor vigor and is not appropriate for a watershed forest.

Red Pine Type

The red pine type occupies 55 acres or about 4% of the management zone. It was established in plantations from 1917 to 1947 making these stands approximately 60 to 90 years old. The red pine on Walnut Hill was planted from 1937 to 1943 and is therefore about 60 to 70 years old.

Plantations were established on a wide range of soil types. Red pine on the moister, more fertile soils tends to be more susceptible to root rot diseases and windthrow. Many of these stands are currently infected by such diseases. For this reason, these stands will be converted to a cover of mixed hardwoods. Overstory removal will precede gradually where adequate regeneration is lacking and more aggressively where it is present. Red pine is best suited to the better drained soils. Plantations on such sites will be converted to a mix of hardwood and white pine or maintained where the plantations are growing vigorously. Red pine will remain a component where natural regeneration exists.

Spruce Type

The spruce type occupies 31 acres or about 2% of the management zone. The vast majority of the spruce that was planted is white spruce. Norway and red spruce were also planted. The most extensive stand occurs in the Stony Brook compartment. Approximately 36 acres were planted in 1917 of which 18 acres still exists. The balance of the spruce was planted from 1928 to 1942 in small patches at a variety of locations.

The general condition of the Stony Brook plantation is poor although the site is well-suited to growing spruce. As is the case with all Sudbury plantations, the tightly spaced trees were never thinned resulting in an over-stocked, small crowned stand. As individual or small groups of trees die or are blown over, the remaining nearly 100 foot tall spruce were ill-equipped to stand on their own. The result was the acceleration of the disintegration of the plantation. A silvicultural operation in 1998 was designed to secure and release a new age class of primarily hardwood species.

5.2.1.10 Management of OWM Lands in the South Basin

The South Basin, which includes the main brand of Sudbury River in Westborough, Hopkinton, Ashland, and Framingham, is hydrologically separated from the Sudbury Reservoir and has not been used for water supply since 1912. MWRA policy states that these water sources (Sudbury River and Framingham Reservoirs No.1 and No.2) should not be considered for future use within the OWM/MWRA system (Yeo, 1991). Management of the approximately 875 acres of OWM lands in the South Basin is thus based on a different set of premises than the North Basin, including the following:

- OWM will manage lands utilized as local water supply sources to protect these sources (e.g., Cedar Swamp and Westborough town wells and future wells).
- Lands that do not have direct bearing on drinking water supplies will be managed primarily for uses such as wildlife management or education. OWM will consider proposals to transfer these lands to a more appropriate authority, such as a local municipality or the Massachusetts Department of Fish and Game, Division of Fisheries and Wildlife.

5.2.2 Conservation Management Practices for Water Supply Forestry

Forest management on OWM properties on the watersheds of the Sudbury reservoirs is conducted to improve the protection of the drinking water supply. Short-term impacts from forest management practices must be exceeded by the long-term benefits to water quality protection. Accomplishing this objective requires strict compliance with management practices designed to protect against losses of sediments and nutrients to adjacent water resources. Described below are specific Conservation Management Practices (CMPs) designed to protect water supplies, which are the standard for OWM's forest management. It should be noted that OWM meets or exceeds the requirements of both the Forest Cutting Practices Act and the Wetlands Protection Act (MGL Chapters 132 and 131). Whenever these regulations are revised, OWM management practices will meet or exceed the revised standards.

Strict adherence to OWM 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 that protect the water supply. 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. A given forest stand is treated, on an average, every 25-30 years, and at that time 1/3 or more of the overstory may be removed to establish and release forest regeneration. The process of removing trees can impact the forest and soils essential to water quality if not carefully designed, implemented, and monitored.

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, CMPs 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.

5.2.2.1 Planning 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 constraints placed on logging that must be factored into planning and logging schedules. 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.

Logging Equipment

Logging equipment has changed dramatically in the 30-40 years that forest management has been active on OWM 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 forwarders with 70-100 hp, widths of 7-8 feet, and weights of 6-8 tons. Skidders drag logs attached to a rear-mounted cable and winch, while forwarders carry logs on an integrated trailer.

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 (usually on tracks) fells, de-limbs, and cuts trees, leaving piles of logs or cordwood, which are retrieved by forwarders.

Small skidders are desirable for most intermediate thinnings on OWM watersheds, while larger models may be acceptable for regeneration cuttings limited to frozen or dry conditions. Combinations of small, maneuverable feller-bunchers and forwarders, small skidders and forwarders, and tracked feller-processors and forwarders have all worked successfully on OWM watersheds. There are combinations of equipment that typically work on various types of harvesting operations on OWM properties (Table 14).

TABLE 14: HARVESTING METHODS/EQUIPMENT USED ON OWM 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 feller/processor with forwarding	✓	✓	

TRACKED FELLER/PROCESSOR

In an effort to specify equipment that is appropriate on specific soils and within specific forest types, OWM has determined ground pressure and width measurements for most of the equipment common to the area, and specifies restrictions, where needed, in timber harvesting permits. 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 15.

TABLE 15: SAMPLE EQUIPMENT SIZE/GROUND PRESSURE RATINGS

Machine Model	Tires	Width	Ground Pressure
TimberJack 208	23.1 x 26	102"	4.9 lbs/sq in
JohnDeere 440C	23.1 x 26	102"	5.0 lbs/sq in
Franklin 105XL	23.1 x 26	110"	5.3 lbs/sq in
TreeFarmer C4	18.4 x 26	93"	6.5 lbs/sq in
JohnDeere 540	23.1 x 26	105"	6.6 lbs/sq in
CAT 508GR	23.1 x 26	106"	7.1 lbs/sq in
Clark 665	23.1 x 26	114"	7.9 lbs/sq in
Clark 665	18.4 x 24	104"	9.5 lbs/sq in
TreeFarmer C6	18.4 x 34	97"	10.1 lbs/sq in
CAT 518	18.4 x 34	99"	11.2 lbs/sq in

Some of the logging equipment available is too large or heavy to meet OWM requirements in certain vegetation or soil conditions, and 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. OWM specifies equipment requirements for each site in its timber harvest permits. This includes machine width and ground pressure limits, as well as specific equipment requirements (e.g., forwarders). 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 not more than 9 feet (108"). Larger machinery may be permitted in regeneration cuts.

An example of a "preferred logging system," that accomplishes OWM goals under difficult conditions is a small feller-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 damage to roots, stems, crowns, or soils. 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 pines, with minimal damage to the young growth.

Most feller-processors are limited to stable ground conditions (few rocks and gentle slopes) and trees less than 16" DBH. In older multi-aged stands where the trees are much larger, 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.

Matching logging systems to soil, topography, and silvicultural conditions is implemented by fine tuning general categories (Table 16) to the specific situation.

TABLE 16: HARVESTING METHODS/EQUIPMENT USED IN VARIOUS SOIL/TERRAIN COMBINATIONS
(Note: The methods listed in Table 16 are taken from Table 14.)

	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	Harvesting Methods 1-8	Harvesting Methods 1-8	Harvesting 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	Harvesting Methods 2-6	Harvesting Methods 2-6	Harvesting Methods 2-6	Methods 2-6 with frozen or dry soils only; ground pressure < 8 lbs/sq. in	NA
Slopes Greater than 20%	Harvesting Method 2	Harvesting Method 2	Harvesting Method 2	NA	NA

Silvicultural Planning

OWM land management plans have to address present and future cutting practices, landscape aesthetics, cultural resources, wildlife resources, wetlands, and rare or endangered species. 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 logging roads, landings, and small and large group cuts is crucial to the long-term success of silvicultural treatments. In turn, logging operation success is dependent upon careful advance planning (see Figure 6 for an example of silvicultural planning).

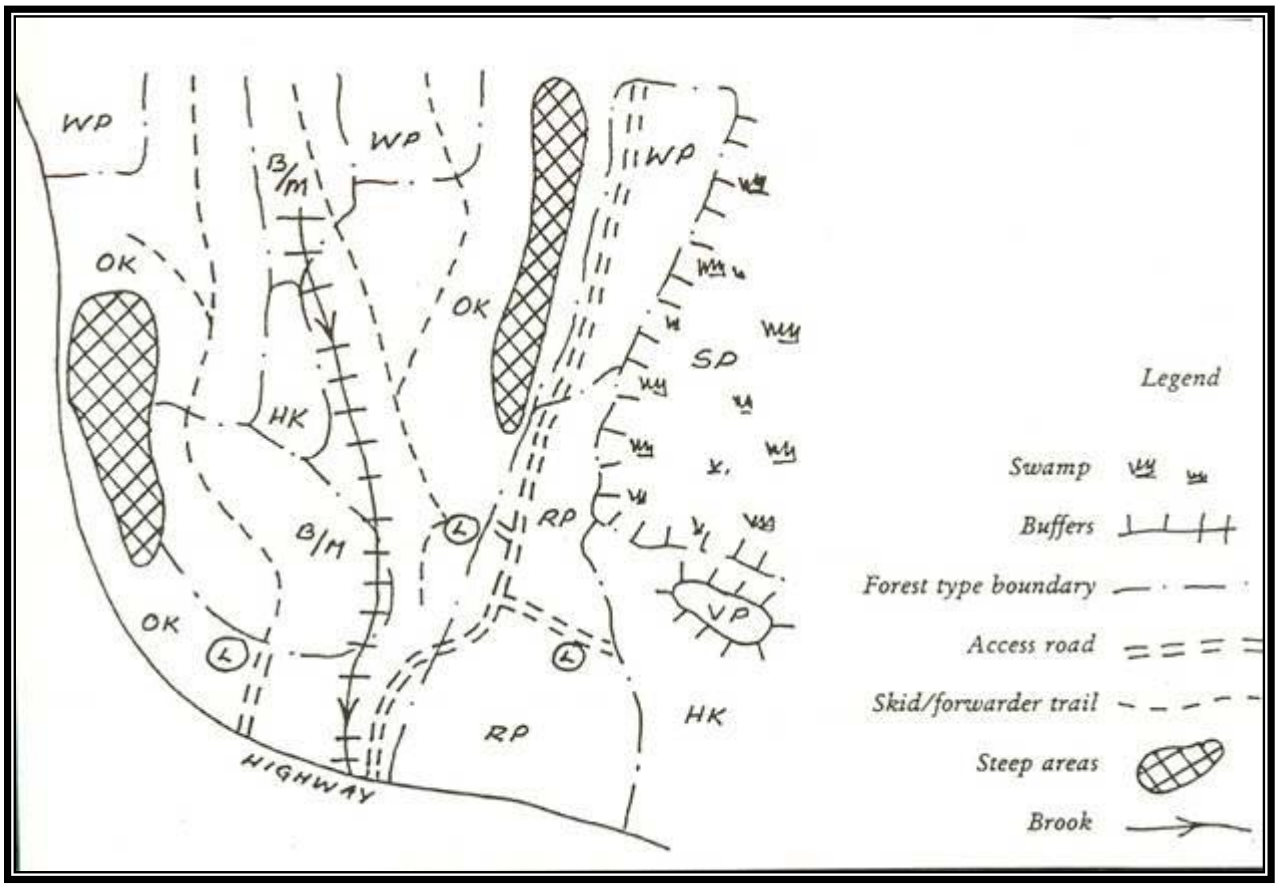


FIGURE 6: HYPOTHETICAL EXAMPLE OF SILVICULTURAL PLANNING

This approximately 200-acre area of OWM 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 buffers 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 preparatory cuttings within the past 25 years, and the understory has developed in response. Additional work in this area will release advance regeneration by removing patches of overstory trees averaging 1 acre in size. Where understory species diversity is limited, further preparatory cuttings will occur, as well as enrichment plantings of appropriate species. 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.

Operator Workmanship

Operator workmanship is one of the most crucial and variable factors in forestry operations. 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. OWM maintains tight control over loggers working on the watersheds through close monitoring, the timber harvest access permit and associated performance bond, and it's right to remove operators who fail to adhere to permit standards. It is important that foresters and loggers develop mutual respect that is based upon a shared commitment to the sustainable stewardship of the land for the protection of the drinking water supply.

5.2.2.2 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 minimum 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 upon slope conditions and along Outstanding Resource Waters (protected public water supplies) and their tributaries, streams that are 25 feet or more from bank to bank, ponds of 10 acres or more, and designated scenic rivers. OWM 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.

5.2.2.3 Buffer Strip

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. Exceptions are allowed for public safety considerations. In certain cases, the entire overstory may be removed to prevent hazardous conditions from developing.

5.2.2.4 Wetlands

OWM's forest management operations will comply with all the requirements of the Wetlands Protection Act, MGL Ch. 131 section 40, and the Forest Cutting Practices Act MGL Ch. 132 section 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 (which include 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 of OWM's silvicultural activities that involve wetland resources are conducted under a Chapter 132 cutting plan, supervised by both OWM foresters and DCR service foresters, and therefore are exempt from Chapter 131 procedures. Exceptions include limited work that does not include harvesting, such as 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, 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, OWM does not allow machinery within low, flat wetland forest with 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 OWM lands at Sudbury are included within the designated wetlands on the watershed. OWM has identified and mapped most wetlands within the Sudbury watershed properties, which are avoided when lot boundaries are drawn for proposed annual silvicultural operations. OWM also adheres to, or exceeds the statewide recommended practices for protection of vernal pools, providing a 15 foot no-cut buffer, a 50 foot no-machinery zone, a 100 foot shade zone, and a 200 foot low-ground disturbance zone (see Figure 7). This vernal pool protection is provided to all vernal pools, whether or not they have been certified.

5.2.2.5 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 gather 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 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 in a custom tailored, case-by-case manner.

FIGURE 7: 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 and No-cut Area — *15 foot buffer around pool*

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.
4. Cut no vegetation within 15 feet of the high-water mark of the pool depression. Silvicultural manipulations are limited to girdling (for instance, to enhance vigor of uncommon swamp white oak trees).

Shade Zone — *100 foot buffer around pool edge*

Objective 2: Keep a shaded condition in this 100-ft.-wide buffer around the pool depression. Amphibians require that the temperature and relativity humidity at the soil surface be cool and moist.

1. No equipment is allowed to operate within 50 feet of the pool edge.
2. Light, partial cuts that can maintain this microclimate are acceptable; clear cuts are not.
3. 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. Keep equipment 50 feet away from the pool depression and winch out logs or wood cut in this first 50 feet.
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 — *100-200 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.

Landings

When determining placement and layout of landings, their size and number are minimized and they are located on soils that will support the logging equipment. Landings are permanent sites and are placed on level and well-drained ground whenever possible. 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 (e.g., road ditch, hay bales) and landings are required to be smoothed and seeded after use. Also, to prevent inappropriate uses of landings, for instance as access points for illegal off-road or all-terrain vehicle use, the access to landings from adjacent roadways will be blocked with logs, stones, or a locked gate if necessary.

Skid Roads

Skid roads are designed to be reused 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 and 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. OWM has rated many commercially available skidders by taking into account their horsepower, weight, load capacity, tire size, and width to determine their suitability for logging on water supply watersheds (see Table 15 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 less than 8.5 lbs/square inch and widths of less than 110 inches are allowed on OWM watersheds. 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, efforts will be made to prevent access by unauthorized vehicles (such as ATV or other off-road vehicles) by blocking access with boulders, logs, or, if appropriate, locked gates. Skid roads are also stabilized to prevent erosion following the completion of the operation. The construction of water bars accomplishes this task. 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.

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, and unauthorized access to these roads will be blocked following the completion of the operation.

Stream Crossings

OWM forestry operations cross streams on a limited basis. For example, from 1978 to 1990, the Division conducted 130 logging operations on the Quabbin and Ware River watersheds that involved twelve stream crossings. Seven of these twelve were across existing culverts, two were mitigated with approved methods, and three were crossings of intermittent streams in dry or frozen conditions. Stream crossings are frequently avoidable on OWM watershed properties because the size of the property holdings often makes it possible to access a given stand from several directions. Frozen conditions are favored whenever 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.

Portable bridging is used to cross all streams with a continuous flow. This bridging consists of either pre-fabricated sections transported to the site (OWM has constructed portable bridge sections for use by private timber harvesters) 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. 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 downstream of the logging activity before, during, and after that activity.

Correct siting of crossing locations 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. OWM 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 Chapter 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. OWM foresters will monitor all unbridged crossings frequently and discontinue or mitigate them if conditions deteriorate and downstream water quality is threatened.

Table 17 outlines the various stream-crossing situations encountered on OWM watersheds and level of protection these crossings are given.

TABLE 17: PROTECTION MEASURES APPLIED TO VARIOUS STREAM CROSSING SITUATIONS

	Level of Protection		
Type of Crossing Situation	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.			✓

Key: "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.

5.2.2.6 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.

Petroleum products: All machines are inspected by OWM 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 minimum of 6 petroleum-absorbent pads (3'x 3') on the machine. Immediate action to contain and stop any petroleum spills followed by prompt notification of the forester is required. The forester in turn contacts OWM 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. Permit specifications require the use of a portable bathroom facility (a minimum of a "Coleman" 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.

5.2.2.7 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 OWM 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 OWM forester before entering the site.

5.2.2.8 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 if the proper logging system is used. OWM permits include the right to suspend operations due to operator inexperience or negligence.

5.2.2.9 Cultural Resource Protection

The protection of cultural resources fits well with watershed protection forestry 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 5.5 for a more detailed discussion on this subject).

5.2.2.10 Aesthetics

Aesthetics can be affected by all of the practices described in the above sections, and are the demonstration of quality workmanship. The maintenance of aesthetics reflects how the logger feels about the work and the land on which it is taking place. This perspective cannot be forced, but it can be encouraged and learned. When work is done correctly it is less conspicuous, but when it is done carelessly, it is obvious to all. These are public lands and the public regularly passes through them 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.

5.2.3 Control of Harvest Operations through Timber Sale Permit

In conducting silvicultural operations that require the removal of forest products from the forest, OWM policy is to protect water quality as well as watershed resources such as soils, residual trees, and cultural resources. The Chapter 132 Forest Cutting Plan, the OWM timber sale permit (discussed below), and the Conservation Management Practices presented in the preceding section address these concerns. In general, the timber sale permit specifies the performance standards, whereas the CMPs explain how these permit specifications are met.

The Permit consists of written specifications, details of 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 four parts: a.) General Conditions, b.) Water Quality Specifications, c.) Harvesting Specifications (including utilization, silviculture, and equipment requirements), and d.) Bidding and Bond Specifications. Parts b. and c. pertain to protecting watershed resources.

5.2.3.1 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 OWM lands as soon as possible. Human waste is required to be deposited in OWM toilets or toilets supplied by the operator.

5.2.3.2 Harvesting Specifications

Harvesting specifications are concerned primarily with the process of cutting trees and removing forest products from the forest. OWM timber harvesting permits specify conditions for lopping slash to enhance decomposition and reduce fire hazards. Specifications are described for keeping slash out of streams and back from access roads. 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 (by indicating the maximum diameter of slash that may be left in the woods). 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 OWM forester and delineated in the field and on the approved cutting plan; 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.

Equipment 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. OWM 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.

5.2.4 Internal Review and Monitoring of Forest Management Operations

The key to the proper protection and management of the resources under the care and control of OWM is its staff, and the care and expertise they bring to their work. Because the foresters walk each acre of land on which forest management occurs, the management controls enforced by this staff are of paramount importance. As the on-the ground implementers of OWM'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. However, it is impossible for any one individual to assimilate all aspects of the diversity of knowledge in the evolving fields of natural and cultural resource management. Therefore, the second key to implementing sensitive management 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 OWM, these supporting disciplines include wildlife biology, forest planning, water quality and environmental engineering, civil engineering, and cultural resource protection. Experts available outside OWM include rare species botanists and zoologists (Massachusetts Natural Heritage and Endangered Species Program) and cultural resources specialists (Massachusetts Historic Commission). OWM 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 OWM's care and control. These professionals and interested non-professionals who spend time studying and exploring the watersheds, contribute invaluable observations that complement OWM'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, OWM has developed the following procedure for the annual review of all proposed OWM forest management activities on the Sudbury watersheds. These reviews are in addition to the general guidelines for cultural and wildlife resource protection.

- Each December, OWM'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 after natural 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).
- Wachusett/Sudbury foresters digitize the maps of the planned operations, which include proximal 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 OWM Natural Resource 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. After reviewing the proposed operations, Natural Resources then forwards copies to the watershed Regional Director, the DCR archaeologist, and the OWM wildlife biologist.
- In 1986, 1990, and 1994 consultants compiled cultural resource maps for Division watershed properties. These maps denote known and likely historic sites. This identification process has not yet occurred for the Sudbury Reservoir watershed. Once these resources are identified, and where forest management is planned for areas containing or likely to contain cultural resources, the DCR archaeologist will identify 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, OWM's wildlife biologist reviews the planned forest management operations. Where necessary, the wildlife specialist 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 specialist, 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 5.4.2 of this plan.
- Each spring, OWM'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 MDC contracted with a professional botanist to review all proposed DWM 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. In particular, these include 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 OWM "Permit to Harvest Forest Products" includes detailed specifications for each harvesting operation. During the operation, OWM 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.

Note: a separate review process is required for proposed access road development or the opening of new gravel operations. For details of this process, see Section 5.1.7.

5.3 Management of Biodiversity

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. 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 critical component to any attempts to incorporate biodiversity into management activities is the need for a large-scale perspective. Management decisions must be made with a landscape, watershed or even a larger regional perspective. Current OWM management activities incorporate a multitude of specific activities that maintain or enhance biodiversity at the micro or stand level (i.e., saving wildlife trees, buffering vernal pools, etc.) However, current OWM management activities often lack the large-scale perspective that is so important to maintaining biodiversity. 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.

OWM's goals for biodiversity focus on either maintaining or enhancing natural ecosystems across the watershed. OWM 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. OWM's primary management activity on these lands is creating small openings in the forest to stimulate regeneration and diversify species. These activities maintain forest cover while mimicking small-scale disturbances that occur naturally.

The Sudbury watershed is an exceptionally difficult place to address the challenges of conserving biodiversity. The watershed is densely populated, fragmented, subject to invasive species, and under intense development pressure. Remaining natural areas tend to be relatively small and isolated. These negative characteristics combine to create a landscape where conserving biodiversity is particularly problematic. However, it is also the existence of these negative characteristics that highlight the qualities of OWM land within the watershed. OWM lands are comparatively large, undeveloped, protected, relatively contiguous, and managed for native species. OWM lands within the Sudbury watersheds represent an opportunity for some native wildlife to exist and thrive.

5.3.1 Biodiversity Mandate

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 state agencies in Massachusetts. 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 species, common or rare that are under protected.

The April 2000 "The State of Our Environment" from the Executive Office of Environmental Affairs (EOEA), acknowledges the link between human needs and healthy, thriving natural communities. EOEA 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, OWM's principal goals for maintaining biodiversity on its Sudbury 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, to eliminate and prevent the spread of non-native invasive species. OWM also seeks to provide the range of seral stages from early successional habitat through unmanaged mature forest across its total holdings.

5.3.2 Rare and Endangered Species

5.3.2.1 Flora


LARGE-WHORLED POGONIA

While no deliberate, comprehensive study of rare plants has been conducted on the Sudbury watershed lands under OWM care and control, studies have been conducted on nearby Wachusett properties. *Isotria verticillata*, the large-whorled pogonia (MA watch list) was the only rare plant species discovered during the 1996 survey of proposed timber-harvesting lots at Wachusett and Sudbury for rare species (conducted by the staff of the University of Massachusetts herbarium). OWM Foresters have also located the following state-listed species during independent surveys of Wachusett properties:

Lupinus perennis	Wild lupine	WL
Arceuthobium pusillum	Eastern dwarf mistletoe	SC
Juglans cinerea	Butternut	WL
Orontium aquaticum	Golden club	T

Although there is no current record of their presence, the species below may occur on OWM watershed properties at Wachusett/Sudbury, based on past records and suitable habitats/range:

TABLE 18: RARE FLORA PREDICTED TO OCCUR ON WACHUSETT/SUDBURY WATERSHEDS

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

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
Cyperaceae	*Eleocharis intermedia*	Intermediate spikerush	T	Aug/Oct
Cyperaceae	*Scirpus ancistrochaetus*	Barbed-bristle bulrush	E	Jun/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
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

Primary responsibility in Massachusetts for the protection of endangered, threatened, or special concern plant species rests with the Natural Heritage and Endangered Species Program of the Division of Fisheries and Wildlife. NHESP has identified 257 species of plants in these categories across the state, and is working continually to design protection strategies. Regulatory support for these efforts exists at both the federal and the state level. The Federal Endangered Species Act of 1973 protects the small-whorled pogonia (*Isotria medeoloides*), which is found in Massachusetts though not yet on the Sudbury watersheds.

Plants are considered rare for a variety of reasons. In some cases, it is simply that Massachusetts is at the northern limit (e.g., Black maple, *Acer nigrum* or River birch, *Betula nigra*) or the southern limit (e.g., Dwarf rattlesnake plantain, *Goodyera repens* or One-flowered pyrola, *Moneses uniflora*) of their range. For species that are generally associated with the eastern deciduous forest, which dominates central and western Massachusetts, plants may be rare simply because they are poor colonizers and thus populations remain widely scattered and sparse. Loss of habitat is also a common cause of plant species loss. Bruce Sorrie, former Massachusetts state botanist, estimated that a surprising 72% of the species extirpated from the state had been lost due simply to the loss of early successional or recently disturbed habitat (Sorrie, 1989). Karen Searcy, current curator of the University of Massachusetts herbarium, reported in 1995 that 13% of the rare species likely to occur on OWM properties rely on early successional habitat or disturbance such as fire to persist (Searcy, 1995). Animal populations are responsible for some losses, either through heavy browsing or through dramatic habitat alterations such as those caused by beaver. While beaver wetlands may provide habitat for some rare plants, they also flood bogs and other uncommon habitats that may have contained rare plant populations. Some species (e.g., Ginseng, *Pallax quinquefolius L.*) have declined directly because of over-collecting. Invasive, non-native plants have also been implicated in the decline of some uncommon native species (see section 5.4.5 below).

Management recommendations for protecting rare plant populations begin with efforts to identify current populations. OWM is committed to working to locate these populations and adding them to GIS databases so that they will appear on maps even at times when they are difficult to locate in the field. Several organizations, including the NHESP in Massachusetts and the Southern New England Forest Consortium, are working to develop specific management recommendations for the perpetuation of uncommon plant species. Much remains to be learned about the specific light, moisture, and regeneration requirements for the species of concern. Some species will persist best if given a wide berth, while others rely on periodic disturbance.

OWM will rely on recommendations being developed to guide management practices around known and discovered rare plant populations. For instance, the Southern New England Forest Consortium has recently published "Rare and Endangered Species: Field Guide for Southern New England," which includes management recommendations. This guide recommends that managers looking to support one-flowered pyrola should "maintain a residual overstory or high basal area in forests where populations have been found" and "thin out understory vegetation." Roundleaf shadbush requires

managers to "prevent woody vegetation from overtaking the site" because "this species does not like a closed forest canopy." OWM will continue to work to identify rare plant populations and to research and apply management recommendations for their protection.

5.3.2.2 Fauna

OWM property within the Sudbury watersheds is within the range of a number of state-listed vertebrate species, only a few of which have been documented to occur there. However, past rare animal surveys may have bypassed OWM land and it is likely that there are undiscovered populations of rare and endangered species on OWM property. Although land protection is one of the most critical factors for survival, protection would be enhanced by knowing where these species are located. OWM actively manages its landholdings, and there is the potential for these activities to impact listed species. While some species may benefit from lack of disturbance, others may require additional management in order to enhance or modify existing habitat.

In order to ensure that land management activities do not disrupt or destroy listed species or their habitats, an accurate and current species occurrence database must be available and expanded. The OWM biologist keeps records of listed species on OWM land that were discovered by in-house personnel or passed along by the public. The state's Natural Heritage and Endangered Species program (NHESP) has a much more complete and detailed databases of listed species. Land management activities carried out by OWM under a Chapter 132 forest cutting plan are reviewed by NHESP. However, routine maintenance (mowing, brush cutting) or watershed maintenance activities (road building/repair) are conducted without a requirement to inform NHESP. In these situations, it is possible to unknowingly impact rare or endangered species. This possibility will be reduced as further surveys and greater sharing of records takes place.

EASTERN BOX TURTLE

In many cases, rare and endangered species become rare because of loss of habitat. One of the greatest benefits of OWM land to wildlife is that it will remain in a natural state and not be developed. However, as mentioned, most of this land will remain covered by maturing forest. This condition will benefit rare or endangered species requiring forested habitat (e.g., sharp-shinned hawk) but will not help other species that require different habitat such as fields (upland sandpiper) or early successional forest (golden-winged warbler). Approximately half the species listed in Table 19 are either dependent on wetlands or utilize them during some portion of their lives. Protecting and maintaining functioning wetland systems is a priority for OWM and should benefit wetland species. In addition, vernal pools on OWM land receive particular attention and protection (see section 5.2.2.4 and Figure 6). State BMPs for vernal pools are being studied to determine their effectiveness in protecting vernal pool dependent species.

Non-forested upland habitat is uncommon on OWM property within the Sudbury watersheds and is limited to maintained open spaces. There are several species in Table 19 that require open fields or meadows. Although OWM will not create field habitat on the Sudbury watersheds, it does recognize the importance of this habitat in the landscape. Therefore, where feasible, OWM will maintain and enhance this habitat on select portions of its land.

Some species listed in Table 19 may be assisted by adequate habitat protection, but still need additional assistance to successfully breed. In these cases, when personnel and resources allow, OWM may provide the added breeding structures or conditions. For example, OWM may construct, deploy, and

maintain floating cedar rafts in the reservoirs if common loons are attempting to nest. Although loons will nest on natural islands, the rafts provide protection from rising and falling water levels. When possible, OWM may also provide nesting structures for bald eagles.

TABLE 19: STATE-LISTED VERTEBRATE SPECIES WITH RANGES WITHIN THE SUDBURY WATERSHEDS.

SPECIES	STATUS[1]	OCCURRENCE[2]
AMPHIBIANS		
Blue-Spotted Salamander	SC	Documented
Marbled Salamander	T	Probable
Spring Salamander	SC	Probable
Four-Toed Salamander	SC	Probable
REPTILES		
Spotted Turtle	SC	Documented
Wood Turtle	SC	Documented
Blanding's Turtle	T	Probable
Eastern Box Turtle	SC	Documented
BIRDS[3]		
Common Loon	SC	Potential
American Bittern	E	Potential
Least Bittern	E	Documented
Bald Eagle	E	Potential
Northern Harrier	T	Potential
Sharp-Shinned Hawk	SC	Probable
Common Barn Owl	SC	Potential
Long-Eared Owl	SC	Probable
Golden-Winged Warbler	E	Potential
Vesper Sparrow	T	Probable
Grasshopper Sparrow	T	Probable
MAMMALS		
Water Shrew	SC	Probable
Southern Bog Lemming	SC	Probable

[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 OWM 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.

[3] Occurrence of birds is limited to breeding pairs, not migratory or seasonal residents.

5.3.3 Rare Natural Communities

A natural community is a combination of physical and biotic conditions that form a functionally distinct area of the landscape (Garrett et al., 2000). An area's physical conditions (e.g., topography, hydrology, geology, etc.) will determine the vegetative composition, which in turn will dictate the type of animal community that lives there. Ideally, to adequately protect and enhance these communities, all features of the system must be properly protected and enhanced, not just individual parts.

Natural communities may be rare or uncommon globally, statewide, or at a local level. To ensure all rare communities receive adequate protection it is necessary to know where the communities are located on the landscape. Unfortunately, OWM has little information regarding rare or exemplary communities within the Sudbury watersheds. Some communities (e.g., vernal pools, Cedar Swamp) are known and documented. However, most communities considered rare or exemplary on a local or regional level have not been mapped. OWM's first step in managing rare natural communities should be to properly classify rare, unique, and exemplary communities that may occur within the watershed. When the classification system has been established, mapping can begin to locate communities. Field inspections of mapped communities will verify mapped areas. Adequate management and protection will maintain the integrity of the critical habitat and surrounding area.

A project to map rare, unique, and exemplary natural communities was completed in 2000 on the Quabbin watershed (Garrett et al., 2000). A classification system tailored to Quabbin communities was developed and preliminary field verifications were conducted. Community mapping and management recommendations were completed in September 2000. Some information from the Quabbin study can be utilized for Sudbury watersheds. Although the community classification system was tailored to Quabbin, many of the communities are rare or unique on a statewide or regional level. For example, talus slopes, pitch pine-scrub oak, hemlock ravines, tupelo swamps, vernal pools, and peat wetlands were identified as rare communities at Quabbin but also occur on other watersheds. Because OWM is constantly acquiring new land, some parcels may contain rare or exemplary communities that have not yet been identified. A complete census of OWM land needs to be done to accurately inventory community types. In addition, a project similar to the Quabbin study should be conducted on the other OWM watersheds to classify rare and exemplary communities.

5.3.4 Cedar Swamp

Cedar Swamp is a state listed Area of Critical Environmental Concern (ACEC) located in Westborough and Hopkinton, Massachusetts. It was the first ACEC in the state when it was listed in 1975. The swamp encompasses approximately 1,650 acres, and OWM owns roughly 27 percent (448 acres). The Sudbury Valley Trustees are the second largest land protectors in the swamp, owning 130 acres (8%). Conrail and Bay State Abrasives are the two largest private owners of land within the swamp's boundaries. Although Cedar Swamp remains a large wetland, is has been affected by past development. A rail line cuts through the center of the swamp from east to west, Interstate 90 crosses the southern portion of the swamp and Interstate 495 runs north to south along its eastern edge.

Cedar Swamp is the second largest remaining wetland area in central Massachusetts. Great Meadows National Wildlife Refuge is the largest (Zilligen and O'Connor, 1994). The swamp is classified as a southern northeast acidic seepage swamp. Seepage swamps are typically located at the base of slopes near the margins of wetland groundwater discharge areas (Zilligen and O'Connor, 1994). These types of swamps tend to be richer in both wildlife species and nutrients than the more common basin swamps. In

addition, Cedar Swamp contains an Atlantic white cedar community which harbors many focal species associated with that habitat type (Clark, 2000).

Although Cedar Swamp has been degraded by development and fragmentation, it is still a unique habitat that provides refuge for a variety of species. There is a diversity of vegetation within the swamp, as well as vernal pools, small streams, islands, and pockets of upland. Several rare species, including the least bittern, pied-billed grebe, wood turtle, and spotted turtle have been documented within the swamp (Starkey, 1990). The swamp also provides habitat for a variety of other species including waterfowl, migratory songbirds, and a diversity of reptiles and amphibians.

A protection plan was developed for Cedar Swamp in 1990 (Starkey, 1990). The plan was developed in conjunction with a variety of public and private interest groups and was funded in part by the MDC. The 1990 plan identified a variety of threats to the swamp including abandoned dumps and landfills, highway runoff, pesticides, and salt-laden snow (Starkey, 1990). The report also included a list of recommendations for the continued protection of Cedar Swamp. These recommendations included conducting further research and monitoring (water quality testing, vernal pool monitoring, wildlife surveys), coordinating with federal and state agencies (salt reduction program, improving highway drainage), implementing local actions (low salt zones, extend wetland buffer zones), and increasing protection and education (purchasing high priority parcels, interpretive signs). It is unclear how many, if any, of these recommendations were implemented and their results.

As a designated Area of Critical Environmental Concern (ACEC), OWM is responsible for preserving and restoring the resources of Cedar Swamp. Specifically, OWM will work to acquire useful scientific data on Cedar Swamp, and to preserve, restore, or enhance the resources of Cedar Swamp, and ensure that activities in or impacting on Cedar Swamp are carried out so they minimize adverse effects on the swamp's natural, recreational, and historic values. In order to try to address these responsibilities, OWM is working to implement the following programs:

1. Inventory wildlife resources within Cedar Swamp, particularly rare or endangered species.
2. Develop a Resource Management Plan for Cedar Swamp that would comprehensively protect, enhance, and restore its resources.
3. Participate with municipalities, nonprofit groups, and individuals in providing technical assistance, management strategies, and public education to ensure the continued stewardship of Cedar Swamp.

5.3.5 Control of Invasive Plants

5.3.5.1 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 awhile for these issues to become apparent. Some of the invasive plant problems on OWM 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 OWM's acquisition of reservoir properties, including Japanese barberry, Japanese knotweed, the buckthorns, 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.
- It 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.

INVASION BY JAPANESE BARBERRY ON RICH, MESIC (MOIST) SITE

5.3.5.2 Problems Associated with Invasives

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 local 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 20 lists the invasive plants that are present at the Sudbury Reservoir.

TABLE 20: INVASIVE PLANTS PRESENT ON SUDBURY WATERSHEDS

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
Black swallow-wort	*Cynanchum louiseae*	Open areas and edges
Shining buckthorn	*Rhamnus frangula*	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

5.3.5.3 Control and Management Options

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." For further information on this Order, see: http://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. This list is published on the New England Wild Flower Society website, at: http://www.newfs.org/conserve/invlist.htm . Strategic recommendations for managing invasive plants in Massachusetts have also been developed by the same group, and are posted at: http://www.newfs.org/conserve/invasive.htm#strat1 .

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 instance, while prescribed fire will reduce invasions of conifers in native grasslands, it tends to stimulate growth and reproduction of many other invaders.

The primary invasive plants found on the Sudbury watersheds are listed below with recommended controls from various sources in the literature:

TABLE 21: MAJOR INVASIVE PLANTS ON SUDBURY WATERSHEDS AND 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.
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 and are NOT OWM policy at this time.

5.3.5.4 Control Efforts during This Management Period

Treatment of invasive plants to control or reverse their spread will progress as time and budget allow, from the highest to the lower priority areas, as follows:

- Areas of invasive plants that are presenting a direct threat to existing rare or endangered plant communities. Control will be focused on area of direct threat.
- Areas where tree regeneration is critical and is being prevented by one or more invasive plant species. This may include riparian zones and other critical protection areas.
- Areas where invasive plant populations are recently established and limited in extent, so that control is a reasonable expectation.

5.3.6 Maintenance of Early Successional Habitat for Landscape Diversity

5.3.6.1 Importance of Early Successional Non-Forested 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 will gradually revert back to forest. Some grassland species, such as the loggerhead shrike and regal fritillary butterfly, have been extirpated from Massachusetts.

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, have 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.

OWM recognizes the regional importance of these open lands to the diversity of wildlife within the state. OWM-owned land within the Sudbury watersheds is 83% forested and 10% non-forested upland. The non-forested uplands are restricted to mowed lawns and other maintained openings encompassing approximately 227 acres. It is unlikely that these non-forested uplands provide quality habitat for grassland dependant species (the average size is 1.5 acres), although they may provide marginal habitat for some animals. OWM does not own any abandoned or reclaimed hay fields in the Sudbury watersheds, which provide better early successional habitat. When possible, OWM attempts to maintain and enhance its non-forested uplands by delaying mowing until late summer to protect nesting birds, limiting mowing to once every 2-3 years to encourage native vegetation, and raising the height of the mower to at least 8 inches to provide small mammal habitat.

5.3.6.2 Importance of Early Successional Woody Habitat

In general, there are 2 broad types of early successional woody habitat. There is successional habitat that is dominated by pioneer species (thickets) and forest habitat dominated by young stands of late successional species (Askins, 2001). Thickets are typically dominated by pioneering species of vines, shrubs, and trees. These habitats tend to be denser than young forest habitats and can persist for longer periods of time in that stage, particularly if actively maintained (power line rights-of-way) or associated with beaver ponds. Young forested habitats are dominated by seedlings and sprouts of mature forest trees, in addition to shrubs and herbs already in the understory. Young forest habitats are much more transitory and may only provide quality habitat for a period of years before the saplings grow and form a closed canopy. Because the two habitats differ in structure and species composition, their value to various wildlife species is also unique. Evidence suggests that since thickets have a larger component of

shrubs, they provide a unique habitat that supports some breeding birds that are not found in young forests (Askins, 2001).

Early successional woody 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.

Species dependent on these early successional woody habitats have been declining since the 1950s as the amount of available habitat continues to shrink (Scanlon, 2000). The Partners in Flight list of regionally declining birds highlights species associated with early successional woody habitat (i.e., blue-winged warbler, Eastern towhee, and prairie warbler). Providing habitat for early successional species involves considerations in both space and time. Young forest habitats are temporal and only support wildlife for 8-15 years. Therefore, either young forest habitat needs to be set back on a regular basis or new areas need to be created. In addition, thicket habitats may also need to be maintained to prevent succession.

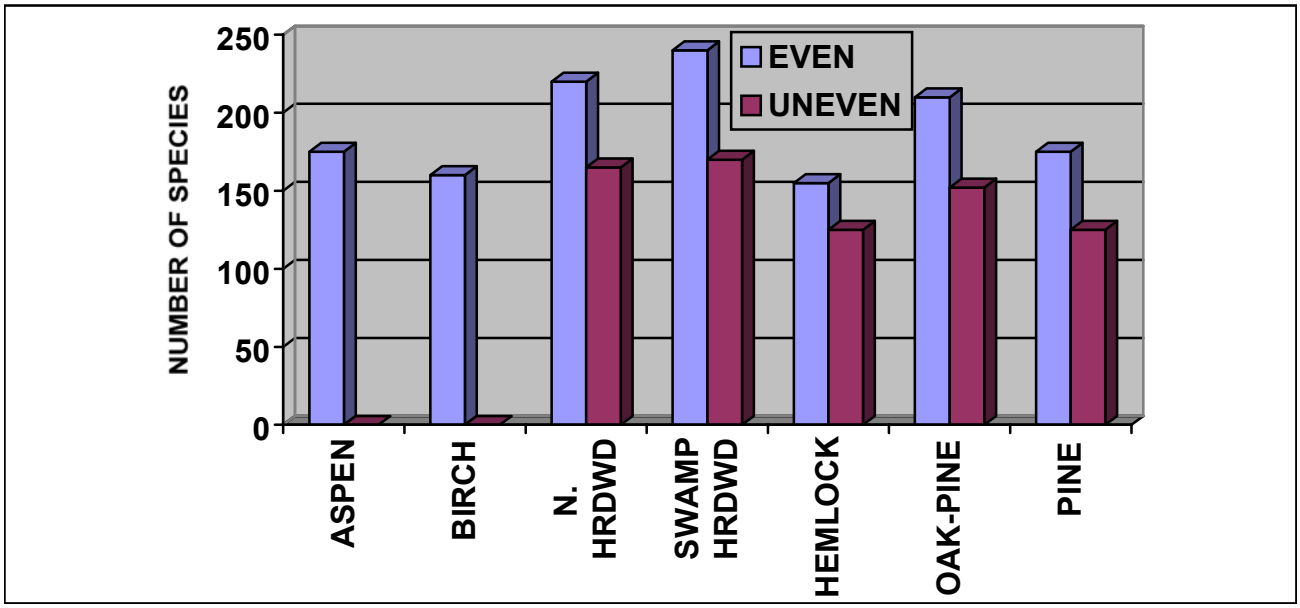
Thicket habitats can exist on power line rights-of-way, shrub swamps, active and abandoned beaver ponds, or abandoned open areas that have been recolonized by pioneer species. Some thicket habitat may persist for much longer periods of time than young forests. Beaver ponds may retain early successional habitat in various forms (ponds, wet meadows, shrubs) for more than 60 years (Litvaitis et al., 1999). Other thicket habitats (power lines, abandoned areas) may require active management to maintain them in an early successional state. Cutting, mowing, burning, and herbicides can be used to regenerate or maintain thicket habitats.

Even-aged forest management is the primary technique used to produce young 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 opportunities for species that are not usually available when uneven-aged management is used (DeGraaf et al., 1992). Even-aged management provides habitat for up to 26% more species than uneven-aged management in similar cover types (DeGraaf et al., 1992) (Fig. 8). Failure to incorporate some even-aged management techniques within the watershed could result in fewer species. Payne and Bryant (1994) state that even-aged management tends to support more wildlife species than uneven-aged management in northern hardwood, hemlock, oak-pine, and pine forests of the northeast. As the current level of tree harvesting within the state is relatively light, widely dispersed, and generally does not provide substantial early-seral habitat, OWM will try to incorporate management techniques geared towards creating this type of habitat. In the end, utilizing a range or combination of silvicultural treatments, rather than strict adherence to one, will eventually result in increased use by a wider variety of wildlife species (DeGraaf et al., 1992).

As mentioned previously, in order to provide the widest range of habitat conditions across the watershed, a variety of management techniques and applications may be needed to either create or sustain various habitat conditions. Although uneven-aged management techniques will be primarily applied across the watershed, it is important to recognize the role even-aged management plays in maintaining biodiversity. However, it is also important to realize that early successional habitat only needs to comprise a relatively small percentage of managed land in order to meet population objectives for early successional species. Further limitations of resources and personnel preclude OWM from managing a

large percentage of their land holdings in early successional stages. Therefore, for this management period, OWM's goal for early successional forested and non-forested habitat will be to try and create or maintain these habitats on appropriate areas when possible. OWM will incorporate areas already in an early successional state (rights-of-ways, maintained open areas) into its resource planning activities in order to maximize the benefit of these habitats.

FIGURE 8: POTENTIAL NUMBER OF WILDLIFE SPECIES BY SILVICULTURAL SYSTEM[A] AND COVER-TYPE GROUPS[B]



[a]Total number of amphibians, reptiles, birds and mammals using each cover type
[b] Taken from DeGraaf et al., 1992.
Even-aged: forests containing regeneration, sapling-pole, sawtimber, and large sawtimber stands in distance units of 5 acres or larger.
Uneven-aged: essentially continuous forest canopies and intermixed size and age classes produced by single-tree selection.

5.4 Wildlife Management

5.4.1 Assessment of Impacts of Planned Management Activities on Wildlife

The management activities described in this plan will have various impacts on the wildlife community at the Sudbury. 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.

The amount and types of habitat at the Sudbury has been dynamic since early colonial times. Once covered by primeval forest, a majority of the land in the Sudbury watershed was cleared for agriculture. This trend persisted for decades, until about 1840 when 75 percent of the arable land was in pasture or farm crops. The next 100 years was another period of dramatic change as most of the farmland was abandoned and new forest invaded. Dramatic changes in the wildlife community accompanied these broad landscape changes. Some species thrived and expanded their range, while other were temporarily

extirpated or became extinct. When agriculture dominated the landscape, species such as black bears, wild turkeys, and white-tailed deer were gone from most of their former range. Bluebirds were abundant during the agricultural period, but are now very rare breeders. Other open habitat species (bobolinks, vesper sparrows, and golden-winged warblers) are declining as well as available habitat shrinks. Today, most of the undeveloped land in the Sudbury watersheds is forested. While OWM's management activities will alter habitat and wildlife species composition, probably the most significant impacts to the wildlife community have been these large regional changes in land use. In addition, human population expansion in the Sudbury watersheds has meant the loss of more and more open space, which is converted to residential housing. Further, large-scale disturbances to the landscape such as the flooding of the reservoir, the 1938 hurricane, and periodic fires have shaped the wildlife community that exists today. Future management will be focused on encouraging regeneration and improving the health and vigor of the forest.

While the management techniques used to reach these goals will not be as dramatic as previous events, it is important to understand how these plans will affect the habitat and wildlife communities on the watershed.

5.4.1.1 General Impacts

OWM'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 the primary objective for a diverse forest cover will mean wildlife communities on OWM land will be dominated by species adapted to forested conditions. Species requiring early successional or open habitat will be less common, isolated to those areas where that type of habitat exists. Open and early successional habitat will be deliberately maintained on a small percentage of OWM land, primarily associated with developed areas (dams, dikes), and beaver impoundments. Forest wildlife communities should benefit the most from OWM's management plan.

5.4.1.2 Specific Impacts

A number of specific silvicultural practices for the modification of existing forest conditions on the Sudbury watershed were presented in Section 5.2.2. These include:

- Preparatory cutting and enrichment planting as needed to establish the next stand.
- Regeneration release cutting, which allows the established regeneration to grow and develop.
- Larger overstory removals in plantations.
- Non-harvest removals on sensitive sites to restructure the forest composition without the disruption associated with harvesting.
- Specific practices in riparian zones.

Described below are the projected possible impacts of these activities on wildlife species and habitats.

Preparatory Cutting and Planting

This type of silviculture is primarily practiced in stands that either lack adequate understory regeneration or regeneration is lacking species diversity. Prep cuts involve opening up the canopy and may also include disturbing the forest floor and planting selected species. As with most types of active management, this type of silviculture involves trade-offs. Thinning the canopy will stimulate the understory and increase vertical diversity within the stand. This should benefit species requiring a developed understory (Eastern towhee, snowshoe hare), but will negatively impact species requiring older, intact forest canopies (northern goshawk, pileated woodpecker). Overall, wildlife diversity within these stands should increase as vertical and species diversity increases, although specific wildlife species may either benefit or decline from the alteration.

Disturbing the forest floor could have a negative impact on those species living on the forest floor, or living in the leaf litter or shallow soil (ovenbird, red-backed voles, and spotted salamanders). However, this impact is temporary and the resultant increase in density of ground cover will be a benefit to these species. Planting desired species within a stand (e.g., conifers) will increase the species diversity of the area and provide a faster amount of understory cover.

Release of Regeneration

Single-tree selection: Silvicultural methods proposed during this 10-year plan focus on group selection (approx. 2 acres) removal of overstory trees to release regeneration. In addition, some single-tree selection may also be used. Group selection has a potentially larger impact on wildlife habitat and species than single-tree selection. Single-tree selection essentially maintains an intact forest canopy and is well suited to regenerating shade-tolerant tree species. Those species requiring continuous forest canopy and large tracts of unbroken forest habitat are favored by single-tree selection because the integrity of the habitat in not altered. Many Neotropical migratory forest songbirds (forest warblers, wood thrush, and ovenbird) are edge sensitive species that require unbroken tracts of forest to successfully breed. When single trees are removed from the forest, no edge or transition habitat is created and the forest interior is maintained. While this will benefit these edge sensitive species, those species that rely on edge habitat (ruffed grouse, white-tailed deer, Eastern towhee, chestnut-sided warbler) will be limited to areas where it exists.

Group selection: A good deal of attention has focused on the potential problems of forest fragmentation in the northeast. Most of this effort has centered on Neotropical migrants and the continued decline of some species. It has been shown that area-sensitive songbirds do not reproduce well along edge habitats (Sullivan and Brittingham, 1994). In most cases, when trying to conserve edge-sensitive species, it is recommended that extensive areas of contiguous forest are maintained and the amount of edge habitat minimized. Because the Sudbury watershed is a mosaic of habitat types and represents a fragmented landscape, it is hard to speculate how much impact OWM land management activities will have on edge-sensitive species. Alterations to OWM forested land is not analogous to what would occur if the same land were developed for residential housing or agriculture. However, since OWM proposes to use group selection (approx. 2 acres) to treat a majority of their stands, it is prudent to consider the impact of this practice on wildlife communities.

The most influential factor associated with this type of silviculture would be the introduction of edge effects. Many studies have documented the reduced nesting success of songbirds near forest edges when compared to the interior (see Wilcove, 1988). This reduced success is a result of nest predators

(blue jays, chipmunks, raccoons, crows) and/or nest parasites (brown-headed cowbird). In addition, rates of cowbird parasitism increase near openings within large forest tracts (Wilcove, 1988). Initially it might appear that edge effects would be limited to isolated woodlots surrounded by houses or barren land. On the larger blocks of OWM land at the Sudbury, there is primarily a matrix of interconnected forest at different stages of succession. Unfortunately, edge effects are applicable to forest ecosystems because small openings within forests create edges.

Although most changes in vegetation caused by group selection extend only 30-100 feet into the forest, increases in nest predation and parasitism may extend as far as 1,000-2,000 feet into the forest. Therefore a small number of openings in the forest could impact a large area. Adding to the problem could be the nature of the Sudbury watershed. OWM land often abuts other non-forested areas or small woodlots where large numbers of nest predators potentially live and reproduce (residential areas support cats, raccoons, bluejays, etc.). Therefore, predation rates could very likely be higher in the adjacent forest openings.

Impacts of fragmentation on mammals are less well known. It is likely that species most sensitive to forest fragmentation were extirpated long before they could be studied. Mountain lions, wolves, elk, and woodland bison have been gone from the watershed for decades. As a result, those mammals left within the watershed are the ones adapted to surviving in fragmented, human-altered landscapes. It is likely that the main limiting factor on mammal populations is human disturbance and not fragmentation.

Openings within forests do benefit some wildlife species, which depend on herbaceous and early successional forest habitat. Wild turkey, ruffed grouse, Eastern towhee, red-shouldered hawk, and white-tailed deer will benefit from the proposed openings. Forest openings will allow for denser ground cover, increased light, and a more open canopy. This type of habitat favors certain species of wildlife.

Large Removals of Plantation

A full overstory removal in plantations produces the greatest immediate change in habitat. Full overstory removal is essentially even-aged management and involves both positive and negative impacts to wildlife. In general, removing the overstory will provide excellent early successional habitat that is utilized by a variety of species. Early successional species will particularly benefit from this management because the larger stand size will attract and sustain larger populations of those species. Those species requiring continuous forest canopy will be impacted by these treatments. In addition, species utilizing conifer-dominated habitat (red squirrels, some Neotropical migrants, nesting raptors) may be displaced by the removal of conifer plantations.

Non-harvest Removals on Sensitive Sites

There are areas on the Sudbury watershed where a reduction of overstory trees is desirable in order to diversify age structure, but where conventional harvesting may be impossible or risky (e.g., a shoreline plantation or a hurricane exposed island). On a limited number of these sites, OWM proposes to cut trees but not remove them. This practice would enhance forest regeneration without negatively impacting the sensitive site. Non-harvest tree cutting would add course woody debris to an area, particularly large size log classes that are important to a variety of wildlife. In addition, removing some canopy trees will increase species diversity and enhance the ground and shrub layers of the area.

Riparian Zone Management

OWM is proposing the non-harvest removal of trees along riparian wetlands within the Sudbury watersheds to increase light and stimulate regeneration. Cut trees will be left in place along the riparian area. This will add course woody debris, providing additional cover and nutrients for forest floor wildlife. In addition, the additional light will allow for a greater diversity of understory trees and ground cover. This will benefit wildlife species that benefit from a denser understory layer of vegetation.

This management practice could have potential negative impacts on the wildlife community depending on where the harvesting was to occur and how many overstory trees were removed. Removing a large number of deciduous trees along the riparian zone could have potential negative impacts to species requiring large expanses of continuous wooded streams. However, if single trees or small groups are removed, these impacts would likely be minimal.

When harvesting trees along the riparian area it is important to try and save cavity or potential cavity trees. Cavity trees along riparian wetlands are extremely valuable to a range of wildlife species.

A final consideration regarding this management technique would be to recognize that stimulating regeneration and new growth along riparian wetlands might be beneficial to beaver populations. Availability of a winter food supply is an important factor affecting beaver distribution in areas where stable water levels are possible.

5.4.2 Conservation Management Practices for Wildlife Management

OWM 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 OWM 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 OWM 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.

5.4.2.1 Habitat Features and Management Recommendations

Vernal Pools

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, OWM 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, OWM 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 recently identified over 30 "potential" vernal pools on the Sudbury watershed through aerial photos. The location of these pools has been digitized and most were field checked in 2004 to ascertain their status. Locations of documented vernal pools will be transferred to a GIS data layer 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.

Vernal Pool Management Objective:

Locate and identify all vernal pools on its property 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.

Seeps

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 surround trees and shrubs accumulate. This makes them important winter feeding sites for turkey, deer, and other wildlife.

WINTER SEEP

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.

Seep Management Objectives:

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.
- Where seeps are present, schedule harvests to occur on frozen ground or during the driest conditions.
- Avoid running heavy equipment within 50 feet of the edge of A SEEP.
- When feasible, use seeps as the center for uncut patches to retain cavity trees, snags, and other wildlife features.
- In stands where seeps are present, lay out skid trails and roads prior to the harvest when seeps are obvious.

Wildlife Wintering Areas

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. 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 (i.e., 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.

WILDLIFE WINTERING AREAS

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 Management Objectives:

Maintain 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.
- When feasible, schedule forest harvesting operations during December-April within WWA 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 to maintain travel corridors (unbroken, dense softwood cover 60-100m wide) that connect all areas of the WWA.

Mast

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.

a. Hard Mast

The oaks are the most important source of mast in the Sudbury watersheds. Hickories comprise a relatively small (1%) 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, 1997). 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.

Hickory trees comprise a much smaller component of the Sudbury watershed forest. Hickories are scattered around the watershed, usually interspersed with oaks. 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.

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 pine are the most widely distributed trees at the Sudbury. Mice, voles, grosbeaks, and finches are a few of the animals that utilize conifer mast. Chickadees and goldfinches prefer hemlock seeds.

b. Soft Mast

Black cherry trees comprise a relatively small percentage of the Sudbury watershed forest canopy. However, 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.

Mast Management Objectives:

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.
- When possible, save all hardwood mast trees that occur in conifer plantations.

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 caches, dwellings or dens, nesting under bark, over wintering 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 the Sudbury. Thinnings, salvage, firewood cutting, and windthrow will result in wildlife tree loss. However, OWM's use of uneven-aged management 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 22).

TABLE 22: OPTIMUM NUMBER OF SNAGS AND DEN TREES PER 100 ACRES BY BROAD HABITAT TYPES

	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

Source: Payne and Bryant, 1994

[1]Animals here need den trees because creating snags by deadening trees is not recommended in these land-use patterns.

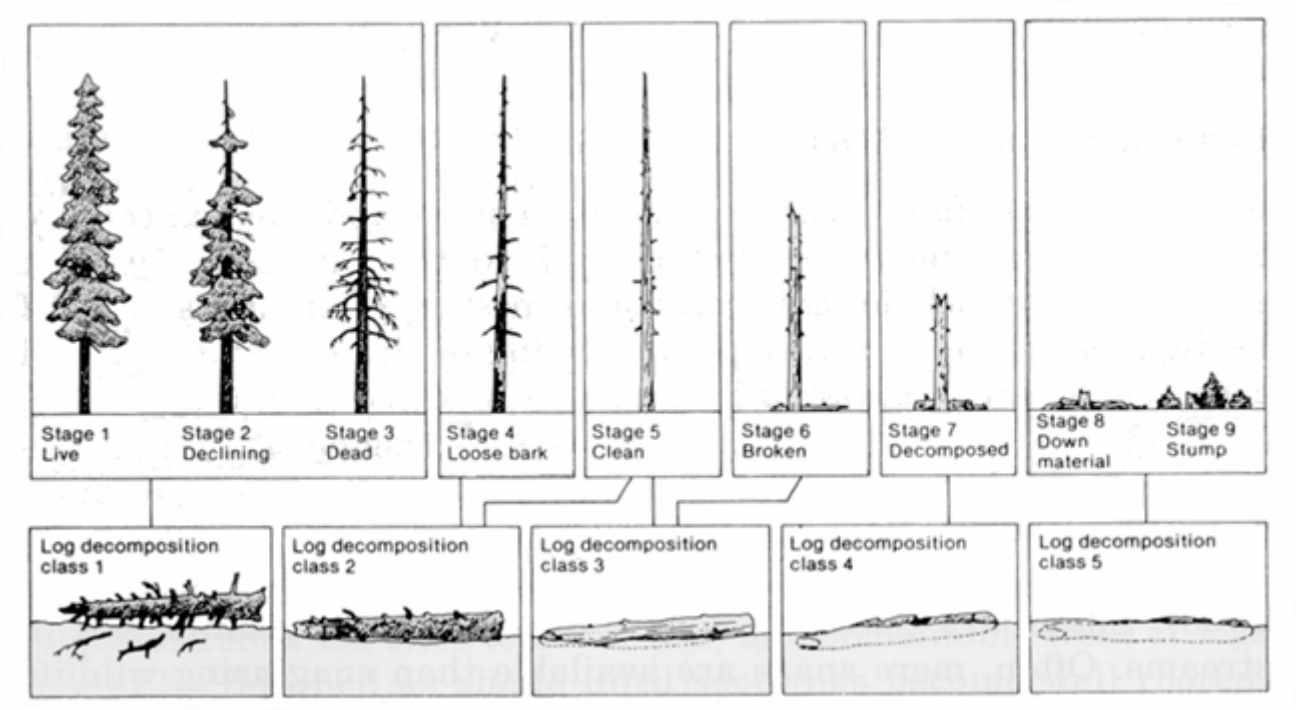


FIGURE 9: DECOMPOSITION STAGES OF SNAGS AND DOWNED LOGS

a. Snags

As a tree dies, it progresses through several stages of decay (Fig. 9) 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 snags 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' is ideal. 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 23).

TABLE 23: NUMBER OF CAVITY TREES NEEDED TO SUSTAIN NEW ENGLAND WOODPECKERS

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)
		D.B.H (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.

Snag Management Objectives:

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. Retain poorer quality trees in areas where good den trees are lacking until better trees develop.

Recommended Practices:

- When possible, leave all snags 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.
- If snags must be felled during management operations, then leave them in place instead of removing them.
- When possible, identify 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 salvaged.

b. Den Trees

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.

DEN TREE

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 (i.e., 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.

Den Tree Management Objectives:

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. Retain poorer quality trees in areas where good den trees are lacking 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 dens trees within 100 feet of a wetland or riparian area.

Downed Woody Material

DOWNED WOODY MATERIAL

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 would occur naturally.

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.

Downed Woody Material Management Objectives:

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:

- If snags must be felled during management operations, leave them in place
- Avoid damaging existing downed woody material during harvesting, particularly large (>16" dbh) hollow logs and stumps.
- When possible, leave at least 4 logs of decay class 1 and 2 per acre (Fig. 9); at least 2 of these logs should be >12" dbh and >6 feet long. Hollow butt sections of felled trees can be used.
- Retain as many logs as possible of classes 3, 4, and 5 (Fig. 9).
- On slopes, orient logs along contours and place against stumps when possible.
- If clearcuts are done, 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.

Woodland Raptor Nests

Hawks, owls, falcons, and vultures are known as raptors. There are 19 species of raptors that breed in New England, fourteen of which are known or potential breeders at the Sudbury (Table 24).

BALD EAGLE NEST

OSPREY NEST

TABLE 24: ACTUAL AND POTENTIAL BREEDING RAPTORS ON THE SUDBURY WATERSHEDS

Species	Breeding Status	Nest Site Selection
Turkey Vulture[1]	Potential Breeder	Rocky outcrops, ledges, cavities
Osprey	Breeder	Stick nests in trees, snags, poles
Bald Eagle[2]	Potential Breeder	Stick nests in living trees
Northern Harrier[2]	Non-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]	Non-Breeder	Old crow/hawk nest or natural cavity
Saw-whet Owl	Potential Breeder	Natural cavity or woodpecker hole
Short-eared Owl	Non-Breeder	Open fields, heath on Cape/Islands
Peregrine Falcon	Non-Breeder	Cliffs, tall buildings, urban areas

Source: adapted from DeGraaf and Rudis, 1986

[1]Potential breeders are raptors that have not been documented breeding within the Sudbury watersheds, but given the bird's range and habitat requirements it may be breeding or 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.

Most raptors are predators and 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 to more than 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 identify 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:

- Prior to laying eggs, some raptors decorate the nest with fresh branches, usually from a conifer.
- After hatching, whitewash (excrement), regurgitated pellets, and prey remains may be found on the ground near the nest tree.
- 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).
- If unsure, consult with an experienced birder or wildlife biologist.

Woodland Raptor Nests Management Objectives:

Maintain suitable nesting sites for woodland raptors across the landscape over time and avoid disturbing nesting pairs of raptors.

Recommended Practices:

- Contact OWM'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. When possible, do not cut trees 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.
- If an active raptor nest is located before or during a scheduled harvest operation, maintain an uncut buffer of at least 66 feet around nest tree, and do not harvest within 330 feet of the nest during April-June.
- If an active raptor nest can be positively identified as belonging to a common or tolerant species (i.e., red-tailed or broad-winged hawk), then harvesting schedules and buffer zones may be relaxed.
- Retain several super canopy pines near the reservoir shoreline as potential future nest trees for bald eagles.
- Follow appropriate snag tree management guidelines.

5.4.2.2 Considerations During Marking

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 in the field.

Timing of operations

The timing of land management activities can have a dramatic impact on wildlife species. Some species (bald eagles, 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:

- OWM personnel will notify the wildlife biologist when land management activities have clearly disrupted a rare or uncommon species' breeding efforts.
- OWM wildlife biologist will assess the nature of the nesting/denning activities and determine what species is involved, what stage of breeding is occurring (courtship, incubation, brooding) and how they responded to the initial disturbance.
- OWM 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) of fields and open areas should only be done after August 1 to avoid destroying nesting birds and mammals (Vernegaard et al., 1998, Jones and Vickery, 1998). 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, OWM will:

- Continue to gather data on critical and sensitive wildlife and their habitats on the watershed.
- Assess the potential impacts of when operations are conducted on a case-by-case basis to try and avoid major impacts and impacting special concern species.
- When feasible, shift the timing or location of an operation to avoid these impacts.

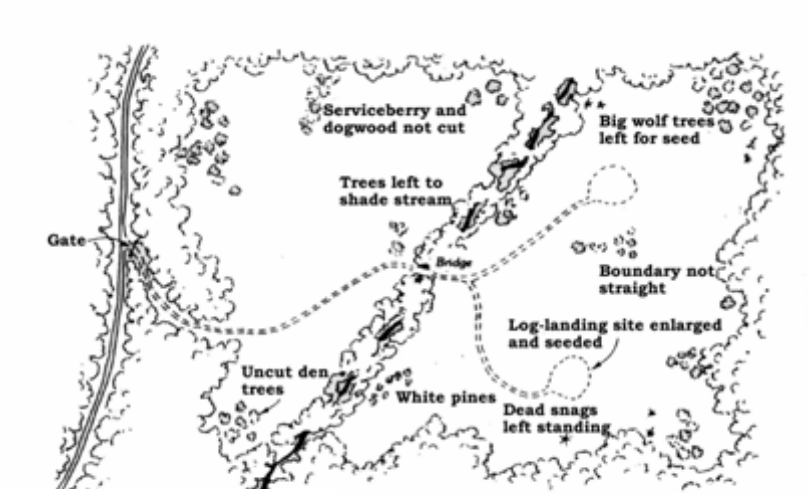
Harvesting Techniques

a. 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 (Fig. 10). In addition, creating an irregular, feathered border will help reduce nest predation and parasitism.

FIGURE 10: FOREST OPENING PLANNED WITH WILDLIFE CONSIDERATIONS



Payne and Bryant, 1994

b. Logging and Skid Roads

Access roads are used by OWM to remove wood, control fires, maintain watershed structures, and aid in navigation. Most OWM roads within the watershed are narrow, grassy woods trails often referred to as logging roads. OWM's use of uneven-aged forest management requires harvest operations to extend over a relatively large area and use comparatively short rotation times (20-30 years). As a result, a network of roads are created and maintained.

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 also determines its impact, as do its proximity to wildlife habitats and travel routes. 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 OWM property constitutes a relatively permanent change in the habitat structure of the area. Because traffic on OWM 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. Studies have documented this barrier affect for small mammals, amphibians and invertebrates (deMaynadier and Hunter 2000).

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 if possible, existing roads should instead be upgraded.
- 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.

- When possible, abandoned logging roads, skid trails, and landing sites should be seeded with a grass-legume mixture.
- Road intersections should be angled to limit line of sight.
- Large-crowned hardwood trees should be left at the road's edge to provide shade and leaf litter.

c. Record Keeping

OWM foresters and other natural resource managers spend a significant amount of time walking, observing, and assessing lands within the Sudbury watersheds. 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 must be reported to OWM wildlife biologist so that records may be routinely maintained and updated.

d. Miscellaneous Considerations

In general, OWM's silvicultural practices include cutting trees with weak crown forms that are more susceptible to damage. Some of these trees have wildlife value, and OWM 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 Population or Impact Control Plans

As a water supply reservoir, OWM's primary responsibility is to the long-term adequate protection of the drinking water. In recent years, OWM has identified certain wildlife species as posing a real and persistent threat to the integrity of the water or watershed structures. As a result, OWM has spent a good deal of time addressing these wildlife concerns. In general, it is OWM's policy not to interfere with natural wildlife events. However, when wildlife activities impact either the water quality of the reservoir or the integrity of watershed structures or resources, then OWM takes an active role in mitigating these damages. The species of concern and their associated risks are discussed below.

5.4.3.1 Beaver Management Policy

Beaver management issues within the Sudbury watersheds can be broken down into two categories: water quality protection and damage to structures or resources.

Water Quality Protection

There is consensus in the scientific community that beaver can play an important role in the transmission of harmful pathogens to humans through water supplies. OWM recently completed a report that summarizes these concerns and addresses management recommendations for beaver at both the Wachusett and Quabbin watershed reservoirs. For more detailed information regarding this see the report titled Quabbin and Wachusett Reservoirs Watersheds Aquatic Wildlife Pathogen Control Zones (Clark, 1999). This report clearly defines a protection zone around each reservoir where beaver will be eliminated and excluded on a continual basis for water quality protection. The report does not address beaver management for water quality protection within the Sudbury watersheds. As discussed before, the Sudbury Reservoir is reserved for emergency use only. Because it is not an active water supply reservoir, no defined control zone exists. If a situation arises where water quality is being threatened, then these situations will be handled on a case-by-case basis.

Damage to Structures or Resource

Watershed-wide beaver population control is not conducted by OWM. However, the following are examples of situations in which beaver activity may be discouraged, mitigated, or otherwise controlled:

- 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.

When there is a conflict with a beaver colony, the guidelines outlined in the following section will be followed to determine the appropriate response.

5.4.3.2 Guidelines for Determining Proper Mitigation for Problem Beaver

OWM personnel who encounter problem beaver sites should fill out the Beaver Damage Observation Form and return to OWM wildlife biologist and Wachusett/Sudbury Regional Director. Upon review, the wildlife biologist and Regional Director will decide on 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 try to provide the most effective control possible that mitigates the problem. Lethal removal is an option, but will only be used if all of the following criteria for the site are met:

- Beaver are causing documentable (observation, photographs, etc.) damage to OWM 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.
- OWM 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 will be followed:

- The above criteria must be documented (using Beaver Damage Observation Form) prior to any action.
- Beaver will be removed through shooting (12 gauge shotgun), or live-trapping using Hancock, Bailey or cage traps and then shooting.
- Two staff will be present at all time and will include one supervisor. All staff participating will have a Firearms ID card. Any persons using live-traps must be properly trained beforehand by a designated trainer.
- Every attempt will be made to retrieve beaver carcasses, and upon retrieval they 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*, *Cryptosporidium*, or other pathogens.
- The supervisor in charge will document all actions and complete the proper form (Beaver Removal Documentation Form), copies of which will be sent to the Wildlife Biologist and the Regional Director.

5.4.3.3 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. The Sudbury Reservoir has had reoccurring problems with this type of damage. Typically, woodchuck burrows were located on the face of earthen dams and dikes. Lethal control methods were used to remove specific individuals and halt burrowing activity. Burrowing activity will continue to be monitored.

5.5 Protection of Cultural Resources

The Sudbury watershed is rich both in its historical and pre-historical resources. Accordingly, safeguards have been built into OWM's land management program to protect cultural sites and artifacts, both through the identification and mitigation of possible impacts, and through a program of proactive vegetative management around significant historical sites.

5.5.1 Review of Proposed Silvicultural Projects

Without appropriate controls, forest management programs can be detrimental to archaeological resources. 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 sites. Skidding logs can further disturb the soil. Operations also entail clearing areas for landings, turn-arounds, and access roads. Those 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 foundation of OWM's Cultural Resource Management Program at Sudbury is a process for reviewing proposed silvicultural operations. The review involves evaluating and assessing the impacts that harvesting could have on archaeological resources should they exist at any given operation. This process has been developed over the past three years, and is formalized in this section.

5.5.1.1 Internal Review of Cultural Sites on Proposed Harvesting Lots

After marking the boundaries of a planned silviculture operation, OWM foresters submit a *Proposed Harvesting Lot Form* for in-house review (see Section 5.2.4 for detailed description of this process). The form provides a detailed narrative of the proposed operation including: location and size, description of topography, forest cover and soils, goals of silvicultural operations, equipment limitations, notable historic features, plant and wildlife communities, and hydrology. The form is sent to a number of in-house reviewers for comment, including the DCR Archaeologist. The primary analytical tool employed in the review of impacts to prehistoric archaeological sites is the evaluation of *site location criteria,* which are discussed below.

5.5.1.2 Site Location Criteria

Prehistoric Sites

At no time in prehistory did human populations roam haphazardly and endlessly across the landscape. Even Paleo Indians, who were the first human occupants of New England approximately 12,000 years ago, are believed to have maintained an economic subsystem that involved a seasonal pattern of restricted wandering within loosely defined territories (Snow, 1980:152). Over the next 10,000 years, sea levels rose and the forests and vegetative communities became more constant. During this time, Native Americans adapted their tool kit and strategies in order to take advantage of the new resource mixes and opportunities the new environmental conditions afforded. Thus, the pattern of habitat use, and consequently the locations of prehistoric sites and artifacts are largely predictable.

The key criteria for determining the archaeological sensitivity of a given site include:

- Degree of slope (i.e., slope < 5 - 7 degrees).
- Presence of well-drained soils.
- Proximity to fresh water (i.e., within 1,000 feet).

Other variables such as aspect, availability of stone suitable for tool-making, and elevation above sea level may also be important. When one or more of these criteria are met, the site of the proposed silvicultural operation is considered to have been an attractive location for Native American habitation or subsistence activities, and is thus classified as *highly sensitive* or *moderately sensitive* for prehistoric resources.

Historic Sites

WELL-BUILT STONE WALL

In the past, OWM foresters have used original land taking plans as well as direct observation to identify the location of historic building foundations. In 1994, the MDC contracted with Boston University to inventory historic sites on the Prescott Peninsula at Quabbin. This inventory identified sites that were not on taking plans but were on 19th century town atlases. This project also improved the availability of information on the sites identified, by producing a data sheet and a map for each site. The MDC completed the historic inventory of the DWM lands at Quabbin in the fall of 1997. The inventory of the Sudbury OWM lands will be scheduled after completion of the Ware and Wachusett lands. Once completed, this information will be used by the DCR Chief Archaeologist when reviewing proposed silvicultural operations.

5.5.1.3 Harvesting Restrictions and Limitations

For those silvicultural operations planned for sites that have been classified as *highly* or *moderately sensitive for prehistoric resources*, restrictions are recommended on the time of year and the types of equipment and techniques used. By employing restrictions on harvesting operations that minimize ground disturbance, a compromise is achieved that allows the harvest to occur, while affording some protection to whatever archaeological resources may lie buried below the ground.

The following are types of restrictions/limitations that may be recommended for *highly sensitive* areas:

- The harvest should occur during the winter with frozen soil conditions.
- Skidding should not be permitted.
- Three wheeled feller-bunchers should not be employed.
- Feller-buncher-processors, with long reach and weight-distributing tracks, should be used.

For those proposed operations in areas classified as *moderately sensitive,* one or more of the above restrictions may be recommended. As this is a relatively new review process, the details of appropriate restrictions are still being fine-tuned through close interactions between OWM foresters and the DCR Chief Archaeologist, including analysis of past management sites for potential impacts.

In some cases, particularly with large acreage sales, portions of a lot may satisfy some, or all of the site location criteria, while other portions satisfy none. In this case, some of the above harvesting restrictions may be recommended for the sensitive portion of the operation, but not apply in other portions. On rugged upland sites or in previously-disturbed areas that fail to meet the key criteria, no additional restrictions are placed on the operations.

5.5.2 Vegetation Management at Historic Sites

Recognizing the realities of existing and likely future fiscal constraints, OWM has developed a strategy for preserving its historic resource base. The strategy is extremely modest in staff time and cost, but it can have a lasting effect on the survival of historic archaeological sites in the Sudbury watersheds.

Vegetation, if left to grow unchecked in and around stone foundations, and other historic structures like dams, raceways, etc., will ultimately alter these archaeological features. The dislocation of foundation stones and the spalling of cement caused by root activity are among the most immediate threats to some of these cultural resources. Should uncontrolled growth continue, in several cases the existing archaeological remains will be of little value and interest at the time that the Commonwealth is more solvent and prepared to once again undertake protective management.

Accordingly, a limited and selective management program to control vegetation growth in and around archaeological sites and historic buildings and structures is recommended. As a general site stabilization and preservation technique, vegetation management will entail:

- Removal of most small to medium sized brush, saplings, and trees from on, and within archaeological features (i.e., cellar holes and their foundation walls, channelized stream beds, mill dams, and historic buildings.
- Removal shall be 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.
- While manual removal may often be the best technique, in some cases where the terrain is sufficiently level and stable, feller-bunchers may be appropriate. These machines have a long reach that limits the need to bring equipment too close to the structure. They pick the tree up, thus there is no concern about the direction of the fall. The tracks tend to distribute the machine's weight, thereby limiting compaction of buried deposits.

In most cases, OWM staff should perform the vegetation management around historic sites. However, there may be private loggers/contractors who are well known to OWM foresters, are particularly skilled and careful, and could be allowed to undertake the work. At sites that are imminently threatened, and which otherwise fall within a proposed silvicultural operation, it may be prudent to allow the private contractor to perform the selective cutting around historic sites. Contracts could include clauses that direct the logger to take extra care and precautions around cellar holes and foundations. Vegetation management will in most cases require periodic and cyclical treatment depending on the nature of the growth, the condition, and significance of a specific site.

5.5.3 Long Range Cultural Resource Management Initiatives

The following is a list of important initiatives that should be undertaken when funds and staffing are available:

- Inventory historic sites. Identify by age, owner, activities, and buildings. This data has been compiled on more than 45,000 acres at Quabbin and will be used to help list priorities for vegetation management efforts and improve the review of silvicultural operations. Future inventories will cover the remaining OWM lands.
- Enter known prehistoric sites into the GIS mapping system.
- Map areas sensitive for prehistoric sites based on site location criteria and enter into GIS.
- 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.
- Develop educational signage and displays on Native American land use of the region. (Note: The Avery Collection, a small but informative artifact collection, could easily be incorporated into an exhibit).
- Encourage local universities to conduct *archaeological field schools* on watershed lands to further test and refine site location criteria.