From Here Forward:

Changes to the

DEPARTMENT OF CONSERVATION & RECREATION

Division of Water Supply Protection's

Watershed Forest Management Program

Response to Forest Heritage Planning Process and the Science and Technical Advisory Committee Final Report

August 2013

Executive Summary

In response to the Forest Heritage Planning Process outlined by the Secretary of Energy and Environmental Affairs in 2010 and the Science and Technical Advisory Committee's (STAC) final review report, DCR's Division of Water Supply Protection (DWSP) is proposing changes to the agency's forest management program, listed below and detailed in the document that follows.

I. *Improvements in public information*, by posting all proposed and active timber harvests and Ch132 cutting plans online, signage at active timber harvests that describes the management operation and provides direct contact information for the forester in charge, and field tours of harvest sites. Opportunities for public information and input also include annual meetings to review proposed harvesting and a written public comment period following these meetings. In addition, DWSP is working to produce summaries of its Land Management Plans that make an overview of their information more accessible to the general public.

II. *Improvements in the internal lot review process*, including more detailed lot narratives, increased post-harvest review to determine success in meeting objectives, and consistent application of subbasin harvest limitations.

III. *Improvements in forestry oversight* by clarifying the roles and responsibilities of Regional Directors, Natural Resources staff, and Foresters regarding harvesting oversight.

IV. *Revised openings in regeneration harvests*, including clarification of the desirable range of opening sizes to meet regeneration objectives (including short-term restoration practices), changes to reduce the "cookie-cutter"/geometric approach to the layout of regeneration openings, a commitment to greater sensitivity to visual effects of opening shape and distribution, and limited development of "old growth" characteristics in appropriate areas.

V. *Green retention,* which leaves a portion of the live canopy in place indefinitely within regeneration openings, will be practiced in 95% of openings over 0.5 acres. This commitment includes the establishment of a standard for retaining live pole-sized and larger trees as dispersed individuals or aggregated groups, to provide a mid-opening seed source, to better mimic natural disturbances, and to provide visual softening of larger openings.

VI. *Enhanced monitoring of timber harvest effects*, which builds on existing standards by specifying refinements to monitoring the application and effectiveness of Best Management Practices, enhanced short-term water quality monitoring adjacent to timber harvests, and the extension and continuation of long-term monitoring to compare the effects on the water supply of active forest management to those of unmanaged, naturally disturbed areas.

VII. *Addressing invasive plants,* through the completion and posting of the *Terrestrial Invasive Plant Strategic Management Strategy* to summarize the problem, its relationship to logging and other disturbances, and DWSP's approach to monitoring and controlling these plants.

VIII. *Strengthening source water protection within the Wachusett Reservoir watershed,* through a renewed focus on fee acquisition and Watershed Preservation Restrictions and more extensive partnering with other agencies and organizations, in recognition that the highest priority on rapidly developing watersheds is to protect, in perpetuity, as much of the remaining forest cover as possible, as soon as possible.

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Table 1: Acronyms and abbreviations

APHIS	Animal and Plant Health Inspection Services
BMP	Best Management Practices
DCR	Department of Conservation and Recreation
DFG	Department of Fish and Game
DWSP	Division of Water Supply Protection
EQ	DWSP Environmental Quality section
ESH	Early Successional Habitat
FFVP	Forest Futures Visioning Process
FHP	Forest Heritage Plan
LMP	Land Management Plan(s)
MWRA	Massachusetts Water Resources Authority
NHESP	Natural Heritage and Endangered Species Program
NR	DWSP Natural Resources section
OWM	Office of Watershed Management
QWAC	Quabbin Watershed Advisory Committee
STAC	Science and Technical Advisory Committee
TIP	Terrestrial invasive plants
TIPMS	Terrestrial Invasive Plant Management Strategy
WPR	Watershed Preservation Restriction
WRAC	Ware River Advisory Committee

1. Introduction

This document has been prepared to summarize changes in forest management review and implementation, on properties under the care and control of the DCR Division of Water Supply Protection (DWSP), in response to the final recommendations received from the Science and Technical Advisory Committee (STAC) on December 14, 2012 and written public comments that followed.

The DWSP Office of Watershed Management (OWM) is primarily tasked with protecting and providing drinking water to 2.2 million consumers living mostly in the Greater Boston area, from the watersheds of the Quabbin and Wachusett Reservoirs, supplemented as needed by the Ware River and its watershed. This exceptionally clean water supply is treated but not artificially filtered, relying upon the forest cover that dominates its watersheds to function 24/7, on solar power, in perpetuity to maintain the quality of the water it delivers. This forest cover is subjected to an increasingly complex combination of natural and anthropogenic disturbances. To maintain the critical filtration function of the watershed forest, DWSP plans and implements a forest management program designed to increase resistance and resilience by deliberately building diversity in species composition and age structure.

For more than 50 years, this program has maintained the support of the public by applying state-of-the-science 'best management' practices (BMP) during timber harvests, by regularly revising carefully researched Land Management Plans (LMP), and by steadily increasing the involvement of the public, advisory groups, and outside reviewers. The management of the forests that protect this biologically filtered drinking water supply was the first public land management in North America to receive the international Forest Stewardship Council's "Well-Managed Source" certification and has frequently been held up as the standard for forest managers on water supplies and other public land. Yet despite all of the above and a solid track record from over 1,000 successful forestry projects, the program has recently been criticized for a combination of reasons including program modifications, inconsistent practices, and changes in the public's viewpoint.

For the first 30 years of active forest management on the DWSP watersheds, the program focused primarily on silvicultural thinnings that gradually improved the vigor and quality of the forest the agency had inherited. Large openings were also created to convert non-native red pine plantations to native tree species or back to fields (to increase water yield). But changes in water supply focus, from water *yield* (following droughts and in response to increasing demand) to water *quality,* drove DWSP foresters to much greater concern about the overall diversity in these watershed forests and their ability to regenerate and persist following both natural disturbances and silvicultural practices. At Quabbin, this led in 1991 to the first deer hunt in 50 years, following several years of challenging debate, in order to restore this forests' ability to regenerate the full suite of native species by addressing long protracted overbrowsing. DWSP Land Management Plans (LMPs) began to include a greater focus on *regenerating* portions of each forest in order to diversify age structure and species composition to improve resistance to disturbance and post-disturbance recovery. In general, these LMPs recommend annually regenerating approximately 1% of the managed forest at each watershed (approximately 70,000 acres of the 105,000 owned are under active management; annual regeneration target is 500-700 acres across the system). Regeneration silviculture that began in the 1990s required the removal of mature overstory trees and is more intense than improvement thinnings in both effects and appearances. Some members of the public have begun to take more notice as a result, often in response to aerial

photography images posted online, or simply from hiking through treatment areas. Other Commonwealth agencies were also beginning to include more regeneration silviculture in their management, including plantation removal harvests and large overstory removals to create early successional wildlife habitat (ESH). The combination of regeneration harvests and greater public scrutiny eventually resulted in a requirement to comprehensively review the basis for active forest management on public forests in a "forest futures visioning" process (FFVP) that was primarily focused on DCR Forests and Parks, not on DWSP or Department of Fish and Game (DFG) lands.

In April 2010, as the FFVP was coming to a close with specific recommendations from its Forest Futures Technical Steering Committee, Executive Office of Environment and Energy Affairs (EOEEA) Secretary Ian Bowles released his Forest Heritage Plan (FHP), which called for a redistricting of the non-watershed lands under DCR's care and control into Parks, Reserves, and Woodlands and the restricting of commercial harvesting largely to the Woodlands category. Additional harvesting in Woodlands was suspended until the redistricting process could be completed. The FHP also included the requirement for the DWSP STAC to conduct a review of scientific principles guiding DWSP forest management, opening sizes, and the requirement for "green retention" in larger regeneration openings. STAC membership was established, Dr. Paul Barten from UMass Amherst agreed to Chair, and the group met for the first time in June, 2010 and subsequently in August, 2010, January, 2011, and June, 2012. A final report from STAC was received in December 2012, triggering this DWSP response and proposed changes to the program. DWSP will accept written public comment for 30 days following presentation of its recommendations at a joint meeting of the Quabbin and Ware River Advisory Committees (QWAC and WRAC) on February 12, 2013. Public comments will be considered and further changes to the agency's forest management program developed if necessary.

The text of the Forest Heritage Plan that specifically relates to DWSP was as follows:

Review: *Before new FY2011 timber sales on DCR Water Supply Protection forests are finalized, DWSP will have the existing Science and Technical Advisory Committee (STAC) conduct a review of the scientific principles that guide existing Land Management Plan objectives. The STAC will also analyze DWSP proposed changes to implementation on issues such as opening sizes and retention standards. Resulting recommendations will be reviewed by the existing public Advisory Committees and appropriate changes or clarifications to Land Management Plans and future watershed forestry projects implemented. DCR will defer any new timber sales for FY11 until this review is concluded. Habitat management practices will be reviewed in coordination with the Division of Fish and Wildlife (DFW) as part of a broader statewide effort.*

Increase review and oversight *of all existing timber sales to ensure strict compliance with all standards.* ***Implement new transparent process*** *with cutting plans posted online and increased public input opportunities for planned projects.*

DWSP is responding directly to the five summary recommendations included in the STAC report, listed below, and to written public comments it received on this report. The science and practice of water supply protection forestry is steadily evolving, and the DWSP remains committed to learning from the research community, from the Commonwealth public that owns these forests, and from the agency's experiences with management, and then to adapting its practices, with carefully garnered public support and in response to all that is learned along the way.

2. Recommendations from the final STAC report.

The five recommendations from the STAC report are as follows:

1. Develop a 20 to 30 page illustrated plain-language summary of the DWSP system and management plans for a *"Scientific American"* audience in collaboration with the DCR, EEOEA, and MWRA Public Affairs offices. Develop a 4-page system and plan overview document for the same audience; it also should serve as a briefing document for visitors. Both documents should be readily accessible on the DCR website. The 4-page overview should be small enough to disseminate as an email attachment.
2. Continue and enhance source water protection efforts in the Wachusett Reservoir watershed in collaboration with other DCR offices (e.g., the Forest Legacy Program, Service Forestry), private landowners, local communities and service clubs, NGOs (e.g., Nashua River Watershed Association, The Nature Conservancy, Wildlands & Woodlands), schools, colleges, and universities. Systematically explore new approaches such as those in development by the Trust for Public Land, Portland Water District (Maine), Chesapeake Bay Program, Denver Water, and many others to identify promising ways to sustain and enhance the DWSP program (Webb 2012).
3. Re-start active management of DWSP forests using the silvicultural methods, harvest planning, and marking and layout techniques employed on the Hardwick and Pelham blocks of the Quabbin Forest and the Wachusett Forest (i.e., site specific adaptation of the irregular shelterwood method) as a the primary approach to the diversifying stand structure and species composition. Large openings with irregular boundaries and other site-specific ecological features (which clearly differentiate them from the controversial geometric patch cuts that led to the harvesting moratorium) could be implemented with conservative BMPs and strict operational control on hydrologically remote areas to create early successional habitat and enhance biological diversity. This recommendation should not be construed as an endorsement of traditional even-aged management methods that, first and foremost, focus on timber values not watershed protection, wildlife habitat enhancement, or other goals and objectives that are much more likely to—in concert with the other recommendations—restore and sustain public trust. Simply put, silvicultural methods that are inherently controversial should be set aside when they jeopardize the watershed forest management program as a whole. Since these watersheds must be protected and managed in perpetuity, patience, not efficiency, is the key measure of forest stewardship. At the other end of the management and successional continuum, silvicultural methods (i.e., specialized thinning techniques) to deliberately accelerate the development of old-growth characteristics in appropriate stands should be considered.
4. Monitor the effectiveness of BMPs to protect water quality using the USDA Forest Service Northeastern Area regional protocol in cooperation with DCR Service Foresters. Establish a camera post and aiming marker on each harvest site and use annual (or seasonal) photographs to document progress of forest regeneration and change. This should be augmented with sampling and analyses to quantify regeneration. Make these photographs, regeneration data summaries, and an interactive map available on the DWSP website that is updated on a regular basis (e.g., quarterly). This high level of transparency will foster a renewed sense of public trust.
5. Monitor the hydrologic and water quality effects (e.g., turbidity, total suspended solids, nitrogen, calcium, stream water level and velocity, etc.) of active management using a team effort by the forestry, natural resources, environmental quality, and DCR service forester staffs. Water quality monitoring sites should be established in relation to a reasonable number of harvesting operations using a "before and after" and "above and below" or paired watershed approach (before and after on reference and treatment sites). The financial and human resources needed to design, implement, and sustain monitoring should be added to current staffs and budgets if needed.

3. Summary of written public comments on the STAC report

The full text of written public comments received from December 14, 2012 until the comment period closed on January 18, 2013, regarding the contents of the STAC report, is posted online at: www.mass.gov/eea/agencies/dcr/water-res-protection/watershed-mgmt/science-and-technical-advisory-committee.html. Comments were received from seven individuals or organizations. Most were broadly supportive of the STAC recommendations. There were some concerns and requests for additions to these recommendations, including the following:

1. Address the interaction between terrestrial invasive plants and forestry
2. Strengthen the monitoring of both *long-term* and short-term effects of forestry on water
3. Compare managed to unmanaged areas and apply adaptive management principles
4. Improve the consistency in the application of BMPs throughout the system
5. Improve internal communication and supervision regarding forestry
6. Improve public communication via more detailed lot descriptions (online) and field tours
7. Do more proactive general education/public communication
8. Invest more in road and culvert maintenance
9. Consider restarting third-party certification of DWSP forestry
10. Implement specialized thinning techniques to develop old growth characteristics

4. DWSP responses

DWSP's responses to the STAC recommendations and the public comments on these follow below in the categories of 1) improvements in public information, 2) improvements in the internal lot review process, 3) improvements to DWSP forestry oversight, 4) revision of opening sizes, shapes, and distribution, 5) green retention (reserving uncut trees within openings), 6) enhanced monitoring of timber harvest effects on water supply, 7) a strategy for managing terrestrial invasive plants, and 8) further strengthening of source water protection on the Wachusett Reservoir watershed.

4.1 Improvements in public information

Among the immediate requirements by the DCR Commissioner's office following the Secretary's FHP announcement was to make information on timber harvesting lots on all DCR lands more readily accessible to the general public. This was in part in response to a significant increase in requests for such information. Beyond the DWSP commitment to reviewing proposed harvests each year with the Quabbin and Ware River advisory boards, the Commissioner further required all timber sales and their Chapter 132 Cutting Plans to be posted on the internet, to improve public accessibility and transparency of the sale process. Current forestry projects and other DWSP forestry information will be posted at: www.mass.gov/eea/agencies/dcr/water-res-protection/watershed-mgmt/watershed-forestry.html.

To provide more immediate information to the interested public, DWSP will use signs at all active timber harvests to post the Chapter 132 cutting permit, to provide a general explanation for the management of the watershed forest and specific objectives for that site, and to provide information for contacting the DWSP forester in charge. Since adopting this approach at the Wachusett and Sudbury Reservoir watersheds, the foresters there report having had valuable conversations with interested individuals about the scale of the operation in both duration and area, and the reasons behind it. This approach is being expanded to include harvesting operations on all DWSP properties.

Public input regarding watershed forestry projects will be sought in a wide variety of ways including: 1) annual meetings for proposed projects and a written public comment period following these meetings; 2) on-line posting of projects; 3) field interpretative signage; and 4) regular field trips to forestry sites before and after active harvesting, in coordination with other state agencies and stakeholder groups.

The STAC has recommended that the agency develop a 20-30 page illustrated plain language summary of the DWSP system and management plans, in part to make the comprehensive, lengthy, desk-reference style LMPs more easily accessible to the public, as well as a 4-page system and plan overview of the same that can serve as a briefing document. At its presentation of findings in December, 2012, STAC recommended that these summaries should be developed by professionals skilled in distilling large references into more accessible forms. DWSP is working to source the development of these summaries and will post them when finished on the same internet site that currently includes all LMPs (www.mass.gov/eea/agencies/dcr/water-res-protection/watershed-mgmt/plans.html).

4.2 Improvements in the internal lot review process

DWSP instituted a formal internal review process for all proposed timber sales in 1994. The process requires the Foresters to complete a comprehensive description of the proposed harvest, with details on the condition of the soils, the forest, associated wetlands, rare/endangered species that are present, and cultural resources, as well as a narrative on the proposed silvicultural treatment and its justification. Once this description and associated maps have been prepared, the proposed lots receive review and field visits by a variety of non-forestry staff, who verify the compliance of the proposal with existing plans and policies, the potential effects on wetlands and surface water resources, wildlife, and rare plants, the presence of cultural resources of concern, and the needs for improvements in roads, culverts, or landing areas. After this review process is completed, Natural Resources staff (NR) assembles a report on each proposed lot that details any issues requiring changes to the original proposal, which are generally minor but occasionally significant. The Forester then discusses these requirements with NR and others, makes adjustments if necessary, and marks the harvest for sale.

There were no specific recommendations from the STAC report regarding the internal lot review process, but written public comments recommended greater consistency in practices across all DWSP watershed forests. The existing internal review process has been a very useful tool for keeping all staff informed and for assuring that cutting plans are consistent with each watershed's LMP. However, DWSP is aware that there has been some inconsistency in the thoroughness of the narratives and occasionally with interpretations of management policies. Changes have been implemented to address these concerns, including: a) narratives will be required to be more complete (more information on what will be harvested and why) and b) lots will be more regularly reviewed following marking of the trees to be harvested and prior to showing the lot to potential buyers (to make adjustments, if necessary, before a harvesting permit is issued), and following their implementation (in order to verify that the stated objectives were successfully accomplished). In addition, it will be required that all proposed lots are processed through an analysis to verify that they will not exceed the DWSP limit of regenerating not more than 25% of the forest in any given sub-basin within any 10 year time period. The 25% sub-basin limit reduces the possibility of increased yield and associated sediment/nutrient losses. This analysis was applied at Quabbin, Wachusett, and Sudbury for several years and will be performed on every lot proposed in both the Quabbin/Ware River and Wachusett/Sudbury sections, from here forward.

4.3 Improvements in DWSP forestry oversight

Several groups of DWSP personnel are directly involved in forest management decisions, planning, and implementation including the Section Foresters, Regional Directors, the Natural Resources Section and the Division Director. Section Foresters are responsible for identifying, describing, and carrying out timber sales. NR staff ensures that forest operations are consistent with the Land Management Plan and associated silvicultural requirements. To further ensure consistent silviculture is implemented, changes are being made to improve oversight of forestry operations, as follows:

- NR staff will review all forestry lot proposals and identify any proposed actions that may conflict with current objectives or policies. DWSP Foresters will be given these comments prior to marking stands for harvest. Differences of opinion between NR staff and Foresters will be brought to the Director of Natural Resources and Regional Director for discussion and to reach consensus. The Division Director will resolve any remaining differences if necessary.
- Regional Directors will carefully review each proposed forestry site before the bidding process and then will sign-off to approve the project.
- For the infrequent proposals that involve regeneration openings exceeding five acres in size, direct approval by the Commissioner is required.

4.4 Revised openings in regeneration harvests

Regeneration opening sizes, shapes, and distribution have received significant internal and public discussion in recent years. Unlike intermediate thinnings or shelterwood preparatory cuts, harvests that are focused on regenerating portions of the forest to a new age class of trees require the removal of individual and groups of overstory trees in order to establish a diversity of new seedlings and support the growth of existing seedlings and saplings. Trees are variably tolerant of shade, so to regenerate the full range of local species often requires openings sufficiently large to escape the shade of the surrounding overstory trees. Canopy openings on DWSP forests, that provide enough sunlight to support diverse regeneration, fall in the range from 0.25 to 2.0 acres, depending on the height of the surrounding overstory trees, the orientation of the stand, and the shape of the opening.

4.4.1 Opening sizes

4.4.1.1 Standard openings in regular silviculture

The STAC report recommends that regeneration harvesting should primarily follow site-adapted irregular shelterwood methods. The regular shelterwood method of regeneration is an even-aged system, but the proposed DWSP *irregular* shelterwood method will retain overstory trees and protect vigorous midstory and advance regeneration (see *green retention* below) indefinitely within regenerated openings, thereby moving even-aged stands to more diverse, multiple-aged conditions. While research has not established regeneration opening size maximums to optimize water quality protection, DWSP is committed to making the smallest regeneration openings that will accomplish the agency's silvicultural objectives. Openings to be created through regular DWSP silvicultural operations within the irregular shelterwood method will fall in the range from a single tree to two acre openings in size, with an overall average of approximately one acre. This size range has been the standard for many years in the vast majority of Quabbin and Wachusett silviculture, as described in approved Land Management Plans, but

green retention has been less common and will be applied routinely from here forward to gain the multiple-aged advantage of the irregular shelterwood method. Larger openings have been common on the Ware River watershed, due primarily to the priority set for replacing stagnating plantations and large areas dominated by poorly-formed old field white pine with more diverse and vigorously-growing mixes of native species. Maximum openings will be reduced at the Ware River from 10 acres to 5 acres, with at least 60% of Ware River openings under 2 acres in size and up to 40% in openings from 2-5 acres to accomplish restorative priorities (see 4.4.1.2 below). Annually, 90-100% of the openings at Quabbin and Wachusett will be below 2 acres in size, with openings of 2-5 acres used to accomplish restorative practices, but totaling less than 10% of the regeneration openings in any given year.

4.4.1.2 Restorative silviculture

There are forest stands on DWSP watersheds that have developed under conditions that make partial harvesting problematic. These are situations in which past land use practices have resulted in undesirable forest conditions that can be best corrected through the removal of overstory trees in groups that will sometimes exceed 2 acres. These are short-term situations that require one-time corrections to restore the forest to diverse, native species composition that is growing vigorously. They will be very clearly described at the proposal stage, with ample opportunity for public comment and with full internal oversight. Situations that recommend full overstory removals within short-term, restorative silviculture include the following:

1. *Plantations*. Following the original taking of watershed properties for the creation of a water supply, large acreages of farmland were planted to trees (most often white or red pine or spruce) in an effort to rapidly improve the protective cover on these open lands. The original plantings were done with tight spacing and the expectation that the stands would be regularly thinned to prevent crowding and allow for vigorous growth. However, early thinnings were not completed in many stands, so that the stands matured with too many individuals, insufficient growing space, and poor height-to-root ratios, leaving them susceptible to wind and snow/ice damage. Over recent decades, many plantations were converted to fields or restored to diverse native forest cover, but there are remaining untreated plantations that are now also threatened by a recent red pine scale infestation. It is a priority for DWSP to regenerate these plantations to diverse mixes of native species, but partial overstory removals would leave residual trees highly susceptible to damage. Therefore, DWSP recommends full overstory replacement harvests that will sometimes require openings larger than two acres. It is estimated that well under 1,000 acres remain in this condition across all DWSP forests and only a portion of these would require openings greater than two acres.
2. *Degraded stands*. DWSP occasionally acquires forest land that was “high-graded” by previous owners. This practice, while legal, removes the best quality, most vigorous trees (for their timber value) and leaves behind poorly formed, low value, and often low vigor trees. These long-suppressed residuals do not respond well to release and the most successful way to return quickly to a vigorous and diverse stand of well-formed trees is to remove most of the degraded overstory, which may require regeneration openings larger than two acres in size. Not all stands that have been high-graded have been identified. Nonetheless, this practice will represent less than 1% of all of the silviculture conducted during the next decade.

3. *Old field white pine*. At the Ware River watershed in particular, many acres of abandoned farm fields followed a typical New England pattern of regenerating to low density white pine. White pine that grows in these open conditions is particularly susceptible to the white pine weevil, which repeatedly kills the terminal bud, leading to the formation of multi-stemmed "cabbage pine". These individual trees are susceptible to wind and snow damage and are generally of low commercial value due to their poor form. Furthermore, the stands that develop in old fields tend to be low in species diversity. The complete removal of the poorly formed overstory white pine in these stands provides for rapid regeneration to a more vigorous replacement stand with much greater species diversity. At the Ware River, ~2,800 acres of this type remain even after steady efforts to replace them, with stands ranging from less than one acre to 150 acres, and averaging 10-12 acres. Significantly lesser amounts occur on the other watersheds.

4.4.2 Opening shape and distribution

In response to STAC recommendations and public input, new standards and management practices will modify opening shapes and distribution to significantly improve aesthetics, in part by routinely incorporating overstory retention. Adhering to state-of-the-science Best Management Practices and harvesting less than 25% of a subwatershed forest in any ten year period greatly reduce the potential effects of opening shape and distribution on adjacent water quality. In addition, however, there are strong aesthetic differences between geometric, "cookie-cutter" openings and those that have been shaped and laid out less regularly. Furthermore, a greater sensitivity to the physiographic and vegetative variations within a forest often suggests openings with irregular shapes, sizes, and distributions. While there are trade-offs in the operability of the harvest and some limitations on regeneration diversity, openings that follow the land are visually more acceptable than those forced onto it. The aerial photo in Figure 1 (Prescott Peninsula) shows a wide range of regeneration opening styles that have been implemented over the past decade or more. While each of these operations is regenerating well, there are differences in the acceptability of their appearance, perhaps especially from above (a perspective that is now commonly available through Google Earth). Concerns have also been expressed that openings set too close together do not appear distinct, so DWSP will maintain a buffer of at least 100 feet of retained forest between regeneration openings, along their long edges. Through green retention, greater sensitivity to land features, and irregular shape and dispersal of openings, DWSP will work from here forward to better balance silvicultural objectives with these aesthetic concerns.

Figure 1: Regeneration openings, Prescott Peninsula, Quabbin Reservoir

4.4.3 Development of old-growth characteristics

The decline of later-seral stage habitat and the potential for protecting or restoring forest areas with the characteristics of 'old growth' have been widely discussed in the Commonwealth for many years. The STAC report briefly addresses this subject and suggests that a more deliberate effort to accelerate the development of old-growth characteristics using specialized thinning techniques could be considered where it is not in conflict with primary objectives for water supply protection. One public comment expressed a similar interest. The techniques for implementing this practice are described on the MassWoods website (http://masswoods.net/information-on/restoring-old-growth-characteristics) and in the Extension publication "Restoring Old-Growth Characteristics", summarized in the table below (from that publication).

Table 2: Active management to encourage old-growth characteristics

Old Growth Structural Characteristics	Management Practices
Increase the diversity of tree sizes and ages	Harvest single trees or small groups of trees, creating gaps up to 1/4 acre; repeat to create multi-aged stands
Increase the number of snags—large standing dead trees	Girdle (i.e., cut several rings of bark/cambium around the stem to deliberately kill the tree) medium to large cull trees
Increase number and volume of downed logs	Fell and leave on the ground medium- to large-sized cull trees to improve growth of residual trees
Provide for future snags and downed logs	Reserve permanent "legacy trees" within harvested areas
Increase number of large living trees	Thin woods by removing competing, low-quality trees adjacent to the largest, most vigorous trees

Across DWSP watersheds, thousands of acres are identified in the LMPs that are not actively managed (Table 3), but are developing old growth characteristics. In addition, DWSP Foresters have traditionally preserved unusual features within regular management areas, some of which include old growth characteristics. These features range in size and type from individual "legacy trees" discovered and retained within a managed stand to small stands or sections of the landscape that have developed exceptionally old or large specimens of common or uncommon species. Where such areas can be efficiently and effectively treated to enhance old growth characteristics, this practice may be applied. While some of these features can be preserved or enhanced for many years, DWSP recognizes the dynamic nature of the forest and the certainty that every legacy tree will eventually die and that storms or pests will eventually alter, sometimes dramatically, features that had been preserved. This does not make such features less important to try to preserve; it acknowledges that the identification and enhancement of unusual features does not guarantee their long-term preservation and that what is unusual today may be rendered common as the forest changes naturally.

Table 3: Unmanaged areas on DWSP lands

Type of area	Quabbin	Ware River	Wachusett	Sudbury	TOTAL
Wet, steep, otherwise inaccessible	3,980	3,665	2,700	910	11,255
Islands	3,674	0	58	116	3,848
Designated natural areas and reserves	2,241	5,255	232	0	7,728
TOTALS by watershed	*9,895*	*8,920*	*2,990*	*1,026*	***22,831***

4.4.4 Openings to create early successional habitat

The STAC report acknowledges that declines in early successional habitat (ESH) are responsible for declines in wildlife species in the Commonwealth and recommends that openings to create ESH could be made on hydrologically remote areas, so long as they did not compromise the primary objectives of watershed forest management. Concerns about declining ESH across the state have been reinforced recently by the September 2011 publication of the *State of the Birds* report by the Massachusetts Audubon Society. ESH literature suggests that openings to support the reproduction of certain declining wildlife species need to be larger than 10 acres in size, although smaller openings may suffice for other species. The importance of these habitats was reinforced by STAC, and existing DWSP Land Management Plans include detailed coverage of this subject in the context of a water supply protection program. In line with the EOEEA Forest Heritage Plan, DWSP will continue to work with the Department of Fish and Game (DFG) and their Natural Heritage and Endangered Species Program, other state agencies, and NGOs to consider the potential for addressing ESH declines on watershed properties. ESH projects will only be developed and implemented with thorough public review and approval.

4.5 Green retention

Green retention generally refers to the practice of leaving a portion of the live forest canopy in place indefinitely, within regeneration openings. It is this prolonged retention of individual trees or aggregated groups of trees within regeneration cuts that creates the multiple-aged structure of the irregular shelterwood method of silviculture. Green-tree retention that includes overstory trees as well as vigorous trees within the midstory and established advance regeneration in the understory will be a regular component of DWSP regenerated openings from here forward and will be applied according to the standard described below. The intent is that the vast majority of openings in each timber sale will have some level of retention, except within narrow, irregularly shaped openings <0.5 acres in size.

Removing all overstory trees in larger openings, in order to accommodate the full range of desired species, has aesthetic consequences. While shade intolerant species may suffer, other species benefit when some overstory trees remain within openings and control light, temperature and moisture in the regenerating stands. When they are present, retaining vigorous midstory trees and protecting advance regeneration in place prior to the harvest both softens the aesthetic appearance of openings and promotes the multi-age structure that has developed prior to the harvest. Retention more closely mimics the effects of natural disturbances (which typically leaves behind dispersed individuals and/or aggregated patches of trees), and provides for the maintenance of biological legacies such as exceptionally large overstory trees (which provide seed and habitat refugia for wildlife following harvests) and a general increase in overall stand structural complexity.

The STAC report acknowledges the value of increasing retention, but does not include specific recommendations for a retention standard. DWSP has been working to develop this standard for a number of years, to define the conditions under which trees will be left within regeneration openings. Agency Foresters are beginning to accumulate data on this practice, which will further inform the refinement of these standards going forward. Current standards are as follows:

- 95% of openings larger than ½ acre will retain at least 5-10ft^2 of live tree basal area per acre.
- While many openings will reserve existing seedling and sapling regeneration, measured retention will include only pole-sized and larger trees, with an emphasis on large, mature trees.

- Retained trees will be dispersed singly and/or left aggregated in small groups (rarely more than 6-8 trees in groups, except where poles are common).
- Where it is present, advance regeneration (young trees established in the understory by past silvicultural thinnings or natural disturbances) will be protected to the extent possible.

The figures below provide images of a variety of **green retention practices** on DWSP forests.

1.5 acre opening with protected advance regeneration and dispersed overstory retention

One acre group selection in an irregular shelterwood with overstory retention

4.6 Enhanced monitoring of timber harvest effects

The STAC report included two recommendations regarding better monitoring of the effects of timber harvesting. The first of these was to better monitor the effectiveness of Best Management Practices using a combination of a regional protocol developed by the USDA Forest Service for the Northeastern Area (see: www.na.fs.fed.us/watershed/bmp.shtm#FieldGuide) and the establishment of camera posts and aiming markers on harvest sites to capture a chronological documentation of the regeneration of the forest following these harvests. The second monitoring recommendation was for increased sampling of associated tributary water quality above and below and/or before and after

timber harvests, making the distinction between *compliance* monitoring (to meet regulatory standards) and *performance* monitoring (to verify management practice effectiveness in meeting goals and objectives). DWSP responses are detailed below.

4.6.1 Best Management Practices (BMPs)

The Massachusetts Forest Cutting Practices Act (MGL Chapter 132, § 40-46) and its regulations (304 CMR 11.0) require that all harvesting lots with cutting plans must meet a variety of minimum standards for the protection of the forest and associated resources, especially water and wetland resources. There are standards for regeneration, for the retention of at least 50% of the stocking of trees within mandated filter strips along waterways, for stream crossings, for road and landing layout and construction, and for the protection of endangered species, amongst others. The responsibility for implementing these BMPs on DWSP timber harvests is ultimately on the licensed DWSP Forester in charge of administering the sale, but is shared by the logger (also licensed), the Bureau of Forestry Service Forester assigned to the region, and the NHESP. In a 'belt *and* suspenders' approach, DWSP adds layers of BMP restrictions above and beyond Chapter 132 requirements for work around water and on wet soils, for the protection of all vernal pools, for stream crossings, and for treatments that take place within established hydrologically sensitive zones.

DWSP Foresters typically check on active harvests at least once or twice a week, sometimes as often as daily for complex operations with high volume production. DWSP holds performance bonds that are not returned until an operator completes all requirements for "putting the lot to bed", such as clearing the landings of debris and wood products, placing water bars on all steep sections of skid trails, removing all stream crossing structures, and generally grading and stabilizing disturbed soils. Procedures are also in place for reporting and responding quickly to spills of petroleum products. The Forester files a post-operation report when the lot is completed, to track any outstanding difficulties.

While the vast majority of operations proceed without violations of these standards, there is always room for improvement. DWSP is moving to use a more detailed checklist and BMP monitoring protocol that may involve both Forestry and Environmental Quality staffs, in order to more systematically assess both the application of BMPs and their effectiveness in preventing problems. The STAC report recommends the use of the Forest Service Northeastern Area protocol for monitoring the effectiveness of BMPs. DWSP staff have met in the field with DCR BOF Service Foresters to practice the application of this protocol. While the full details of this DWSP commitment to improved BMP monitoring are still under development, the general categories for review will include at least the following:

1. Verification of adequate erosion control at skidder trails, forwarder roads, and landings
2. Inspections of stream crossing stability during and following completion of the harvest
3. Field checks on the handling and storage of petroleum products
4. Verification of adequate control of human waste and trash
5. Records of the presence of and response to any spills of petroleum products
6. Verification of the compliance of the finished harvest with the proposed objectives of the operation for changes to the forest cover's structure and composition

DWSP recognizes that disconnecting the access roads from the water resources is perhaps the most critical component of BMP application on water supply watersheds. The agency works steadily to improve the roads that it inherited and their ability to carry heavy equipment. Ideally, every road in use is well-crowned, well-graveled, and well-drained to direct the runoff of sediments away from adjacent water resources. Culverts must be properly sized and installed to carry the heaviest flows following storm and snowmelt events. DWSP has completed culvert surveys to identify areas in greatest need of improvement and steadily applies available staff and budget to make road improvements that coincide with predicted uses. In response to public comment on this issue, DWSP will provide summaries of proposed road and culvert work as a component of the annual public meetings on proposed forestry.

Finally, DWSP will implement the recommended installation of camera posts and aiming markers on harvesting sites, especially where this seems critically important (e.g. to document the conditions of the overstory and understory prior to and following a regeneration harvest in an area that receives lots of recreational traffic). DWSP forestry offices have been equipped with good quality digital cameras so that this task can become a component of the forester's visits immediately before, during, and immediately after a lot is harvested, as well as over the years that follow. The agency has used this technique to follow changes in regeneration responses (e.g., Fig. 2) in the past and to document gradual declines from pests such as the hemlock woolly adelgid.

Figure 2: Half-acre opening, Prescott Peninsula, 1996 to 2008

4.6.2 Water quality

The STAC final report includes a strong recommendation to increase and enhance water quality monitoring. Specifically, STAC distinguished between *compliance* monitoring and *performance* monitoring and recommended significant increases in the latter. *Compliance* monitoring is required and budgeted mandatory assurance that water leaving the supply system and entering the distribution system meets ever-more restrictive minimum standards for clarity, color, and biological and chemical content. *Performance* monitoring is generally voluntary verification of the effectiveness of management practices in meeting goals and objectives of the supplier. Improvements were recommended by STAC in part because "*The implicit assumptions in DWSP plans about the short-term effects of active management on streamflow and water quality should be explicitly tested.*"

4.6.2.1 Short-term water monitoring

Water quality in the Quabbin and Wachusett Reservoirs, the Ware River, and associated tributaries is compliance monitored by DWSP and MWRA via tests for a wide range of potential pollutants. Annual reports are online at: www.mass.gov/eea/agencies/dcr/water-res-protection/water-quality-monitoring. Sampling for turbidity, a surrogate for total suspended solids and an indication of erosion, is the most standard requirement of DEP regulators for monitoring watershed protection on Massachusetts drinking water supplies. DWSP has used turbidity regularly to monitor stream impacts of problematic land development projects. To improve performance verification for the controls over the effects of timber harvesting on associated tributaries, DWSP has recently increased routine turbidity monitoring of forestry operations, in particular at stream crossings and during storm events, and either above and below the operation or before it begins and after it has been completed, or both.

Division personnel understand the need to periodically measure tributary water quality at timber harvesting operations to make sure that no negative impacts occur. Standard monitoring procedures were instituted in the Wachusett watershed following the latest update of the Watershed Protection Plan (2008) and will be instituted at the Quabbin and Ware River watersheds from here forward. This routine performance monitoring is designed to verify that no short-term water quality problems are associated with active logging conducted on Division lands. Once a forest cutting plan is accepted, Division Foresters will communicate all relevant information to Environmental Quality (EQ) staff. Each site will be inspected by EQ to determine where water resources are present and if sampling opportunities exist to test for impacts from the forestry operation. Baseline sampling will be conducted downstream of the proposed area of disturbance (e.g., a stream crossing) prior to the start of any operations. Monitoring will be done at upstream and downstream locations during and after active logging operations, with a focus on storm event sampling and on sampling during the removal of bridges or pole crossings. Sampling at forestry operations is currently done only for turbidity, but DWSP recognizes that future monitoring may need to add parameters, again per the STAC recommendations, which suggest monitoring turbidity, total suspended solids, nitrogen, calcium, and stream discharge.

Throughout active harvesting operations, it is the responsibility of the DWSP Forester in charge to monitor compliance with water quality protection measures at stream crossings, work near wetlands, or on steep slopes; the conditions of skidder and forwarder roads as well as main access roads and landings; equipment maintenance; and the treatment and placement of slash. Upon completion of timber harvesting operations, both Foresters and EQ staff will confirm that conditions have been stabilized and there are no threats to water quality prior to the release of the performance bond and filing of final reports.

Since 2008, performance monitoring of turbidity has included nine forestry operations in the Wachusett watershed. Sampling at eight of the operations is focused on the possible impacts from stream crossings while one sampling effort was on a parcel in which Asian long-horned beetle host tree removal by the federal Animal and Plant Health Inspection Services (APHIS) program took place and included analysis of the herbicide being used to prevent regrowth of host species (even though herbicide was applied to stumps on the bank of the stream, no herbicide was detected in the stream

water). Elevated turbidity was recorded following bridge removal at two locations, but in both instances the increase did not exceed commonly recorded turbidity levels during storm events at pristine sites, and post-removal turbidity quickly returned to pre-removal levels. Elevated turbidity recorded at other locations was determined to be a function of increased flow following rain and not linked to forestry operations, as there was no significant difference between values at stations upstream and downstream of the forestry operation. The Forestry and EQ staffs in the Quabbin/Ware River section have designed a similar approach to increase performance monitoring during timber harvests on these watersheds. Operations that include stream crossings will be monitored for above and below and before and after differences in turbidity using the following protocol:

- Turbidity samples will be collected monthly above and below proposed stream crossings during both dry and wet weather prior to the start of any activity to establish baseline conditions.
- Turbidity samples will be collected above and below each stream crossing during the installation of all temporary bridges or pole crossings.
- Turbidity samples will be collected weekly above and below each stream crossing during dry weather and during or following storm events throughout active logging operations. If elevated turbidity is obvious in the field at a downstream site, additional downstream samples will be collected to determine the extent of the impact.
- Turbidity samples will be collected during the removal of all temporary crossings and then monthly above and below stream crossings for one year following the completion of all activity.

Water quality impacts can occur at areas other than stream crossings especially if riparian buffers/filter strips or areas with steep slopes are disturbed. The sampling protocol described above is focused on lots that include stream crossings but may also be applied where timber harvesting is taking place within fifty feet of a stream or steep slopes are present. The DWSP recognizes that the most significant potential impacts will occur during or immediately following intense rain or snowmelt events. If the number of active sites and available staff precludes weekly sampling at all locations, monitoring will focus on wet weather events and less frequent dry weather sampling. If sampling identifies water quality problems, that site's monitoring effort will be increased to clarify the source of the problem.

4.6.2.2 Long-term water monitoring

To address the need to explicitly document the long-term water supply effects of active forest management, the NR section began to design studies on the Quabbin watershed and acquire equipment in the late 1990s with assistance from researchers at the University of Massachusetts. First order tributaries located on Prescott Peninsula were chosen as focus areas, in part due to the desirability of completely controlled and fully forested sub-watersheds. The Middle Branch of Dickey Brook serves as the reference watershed, on which only minimal management had occurred during the decades prior to this study. The East Branch of Underhill Brook was chosen as the treatment site on which to eventually apply typical DWSP forest management. Shays Brook was chosen as a site on which to follow stream changes due to natural disturbance, in this case the presence of hemlock woolly adelgid within the hemlock-dominated riparian area of the lower section of this watershed. The upper half of the Shays watershed is without hemlock, so a separate site was identified at the low end of this upstream section of the watershed, to provide an undisturbed comparison to the downstream site.

4.6.2.2.1 Site Descriptions

The tributaries under study and their watersheds are components of the Quabbin Reservoir watershed. Soils range from thick (to 125 cm) and poorly drained organic mucks through well-drained, variable depth (from 2 to 200 cm deep) glacial till soils to excessively well drained deep loamy sands (200 cm or more). Average annual precipitation at New Salem (within the watershed) is 1,270 mm and average annual snowfall at Worcester (48 km southeast of the reservoir) is 1,780 mm. Average precipitation yield to the reservoir is approximately 50%.

There are differences between the chosen watersheds on finer scales, including differences in soils, slopes, azimuth/exposure, and type and distribution of overstory and understory vegetation. However, all of these test sites are first order tributary watersheds ranging in size from 192 to 260 acres (except that Shays Brook Upstream is a 105 acre sub-watershed of the full Shays Brook watershed) and all are subjected to similar local weather.

4.6.2.2.2 Instrumentation and Monitoring

Weather stations

In open fields within or immediately adjacent to the monitored watersheds, NR built simple platforms on which HOBO soil/air temperature monitors (Fig. 6) and HOBO tipping bucket rain gauges (Fig. 7) were installed, to document local weather conditions.

Automated water quality samplers (Hydrolab)

In 1999, NR acquired four automated Hydrolab samplers capable of monitoring temperature, dissolved oxygen, conductivity, turbidity, pH, and depth at any interval set by the user, and of accumulating and storing these data for periods of a month or more (depending on battery life and duration of probe calibration). NR designed and installed frames to hold these units in place (Fig. 3) and initially used them to monitor storm and snowmelt events as well as beginning to acquire background characteristics of the first order tributaries. With careful maintenance, this equipment provides a relatively inexpensive alternative to acquiring and processing hundreds of samples per month.

Figure 3: Hydrolab installed in frame

Monthly grab samples for nutrients

The Hydrolab data probes allowed for capture of basic water quality components, but did not include nutrients or direct measurement of sediments. To begin to characterize this component of tributary water quality, NR requested and was granted limited monthly grab sample processing by the Massachusetts Water Resources Authority (MWRA). Samples have been pulled from these sites every second Wednesday of each month since April of 2002, with minor exceptions due to access issues or dried up streams. Samples include basic draw for total suspended solids, an acid-preserved sample for total phosphorus and total Kjeldahl nitrogen, and a filtered and frozen sample for nitrite/nitrate.

Weirs

While automated water quality monitoring and monthly nutrient and sediment grab samples provide snapshots of conditions within these streams, they do not allow calculation of potential loading of reservoirs by total sediments or nutrients carried downstream. Loading requires measurement of discharge during the same moment as the water quality snapshots are acquired. For small, first order tributaries to Quabbin Reservoir, this was accomplished through the installation of weirs that force the stream's discharge through a V-notch of known angle, allowing volume per unit of time to be calculated simply by measuring the height of the water through the V-notch.

Weirs are constructed by choosing an appropriate location just upstream of the first stream junction and carefully profiling the stream beneath a fixed, level reference line (tight string). This profile is transferred onto sheets of marine plywood and a 120 deg V-notch, plus an overflow drop are cut into the top. The plywood weir sections are spliced and installed on site and braced with fiberglass poles. Pond liner is draped over the upstream side of the weir and 10-15 feet upstream and to the sides. The edges of this liner are secured with sand bags, as are the edges of the weir. A custom formed steel crown, including the sharpened-edge V-notch is secured over the liner and the top of the weir. Additional rock reinforcement is built against the dry side of the weir and beneath the spill point of the V-notch.

Discharge at these weirs is calculated by taking the height (H) of the flow above the V-notch in feet and calculating discharge (Q) using the following formula: $Q = 4.36[H^{2.5}]$ (cubic feet per second). These height measurements are routinely collected during the collection of monthly grab samples. NR has recently acquired water level recorders (pressure transducers) to install at the base of the V-notches, allowing continuous flow measurements and much more detailed calculations of flow, and therefore of loadings.

Figure 4: Shays Brook downstream weir December 2011

The data from this Quabbin study was collected during a sufficiently long calibration period (10 years) to provide DWSP with reasonable mean values for the parameters monitored. NR and EQ staff are currently working through the details for implementing the silvicultural treatment within the forest on the East Branch of Underhill Brook watershed and possible additional sampling in order to complete this test of the long-term consequences of routine DWSP timber harvesting on both water quality and water quantity.

Monitoring of long term water quality impacts from forest management activities in the Wachusett watershed is also being proposed. The EQ staff at Wachusett is designing a long term water quality monitoring plan to begin in spring 2013 to help determine the impacts of active forest management and to test the theory that DWSP BMPs are effective in assuring there are no measurable impacts on stream water quality from timber harvesting operations. Water quality and water quantity data will be collected and used to estimate nutrient loading. These loading estimates from the active forestry site will be compared to loading estimates from the control subbasin and from other subbasins across the Wachusett watershed to determine if the BMPs are effective.

The monitoring effort will utilize paired subbasin sampling at and near a single forestry site in the Wachusett watershed. DWSP Foresters and EQ staff will review possible locations and chose a forested subbasin with no other land use (if possible) where significant logging is proposed. A second subbasin (preferably nearby) with similar topography, land use, and water resources where logging is not proposed will be selected as the control. Downstream sampling locations in both subbasins will be selected. Sites must be accessible and have appropriate characteristics to allow for construction of weirs or the use of the natural channel with a staff gage to establish a rating curve.

Sampling will be initiated before forestry operations begin, continue throughout active logging, and be maintained following the completion of all activity for at least five years. The study will include monthly dry weather grab sampling and quarterly storm event monitoring using automatic samplers. Parameters have yet to be finalized but may include pH, temperature, dissolved oxygen, turbidity, total suspended solids, total organic carbon, ammonia, nitrate, nitrite, total phosphorus, and UV-254.

Regular documentation of tributary flow and of precipitation amounts and intensity will be done. An attempt to collect and analyze overland flow may also be done if feasible.

To supplement water quality sampling data, DWSP aquatic biologists will utilize macroinvertebrate sampling if possible to biomonitor streams in both harvested and control subbasins. Samples will be collected in the late spring (May-June) before and following logging activities. Although most macroinvertebrate sampling is done in perennial streams, biomonitoring in ephemeral streams has been proven to provide useful information.

4.6.3 Comparisons of managed to unmanaged areas within DWSP holdings

In order to further verify the predicted effects of active management, including forest management, the management of terrestrial invasive species, and wildlife management such as deer population control, DWSP will include data collection and analysis on both unmanaged and actively managed areas within its care and control, and provide specific reporting on the results. For instance, as a component of its Continuous Forest Inventory (CFI), DWSP has established permanent plots on islands and within designated natural areas, from which it collects a range of information on the site and its trees and other vegetation. While occasional analyses have been performed that compare these unmanaged sites to growth and development on managed sites, these will now become a regular component of reporting on this decadal inventory.

In addition to CFI, DWSP annually collects information on regeneration development within both managed and unmanaged areas. While there is no routine, repeating inventory of terrestrial invasive plants, a sampling inventory will be designed and implemented to compare the presence and development of these species on both actively managed and unmanaged areas. Finally, most, but not all DWSP properties at Quabbin are now regularly hunted to maintain control over the impacts of the deer population on the growth and development of the understory. Regeneration surveys have for many years compared areas with and without hunting and with and without active forestry. These surveys will include more transects within areas fully reserved from both hunting and active forest management, such as islands, in the future.

Findings from each of the studies above will be made available to the public through internet posting.

4.7 Completion of the DWSP Terrestrial Invasive Plant Management Strategy

While STAC chose not to directly focus on this topic, the increasing problems associated with the expansion of invasive plant species are well known by the agency and increasingly described in the popular press, as public awareness and concern grows. On forest-filtered water supplies, such as the DCR/DWSP system, terrestrial invasive plants (TIPS) are problematic for at least the following reasons:

1. Invasive plants can monopolize species composition, reducing biological diversity and therefore the resilience of the land cover in response to disturbances.
2. These plants simplify structural complexity of the watershed cover, again making it less resilient in the face of the wide range of natural disturbances that impact structure.
3. TIPs on DWSP properties are predominantly herbs, grasses, shrubs, or vines, which provide less protection than the tall, deeply rooted, and structurally diverse forest cover.
4. Many of these TIPs compete directly with tree regeneration, preventing the continuous replacement of forest cover.

5. Some TIPs, including Japanese barberry and microstegium grass increase pH and nitrification in eastern forests, with potential consequences to water quality in adjacent tributaries. The presence of invasive autumn olive can increase nitrate leaching during the dormant season in fields previously occupied by native early successional plant species. In addition to these and other potential effects on water quality, evidence is growing that invasive plants can significantly alter water yield due to differences in evapotranspiration and uptake rates.

In response to these concerns, DWSP has been monitoring terrestrial invasive plants for the past twenty years and more intensively during the past 5-8 years. The Natural Resources section has recently completed its Terrestrial Invasive Plants Management Strategy (TIPMS) for properties under the care and control of DWSP (www.mass.gov/eea/docs/dcr/watersupply/watershed/dcrwatershedterrestrialinvasivesstrategy.pdf). This report further details the problem and its extent based on recent DWSP inventory, outlines principles for management and control, and lays out priorities for management. These priorities include 1) buffering rare plant populations, 2) early detection/rapid response to new invasions, 3) protection of forest regeneration near intakes, 4) control of invasives within proposed harvest areas, and 5) protection of biological diversity in wetlands.

Relative to the recommendations of STAC, the TIPMS includes silvicultural recommendations to reduce invasions as well as requirements for cleaning equipment. When invasives are present in the vicinity of a proposed harvest, the cutting will be modified to allow tree regeneration but reduce the stimulation of invasive species, when possible (specifics depend on the growth habit of the invasive – e.g. vine versus shrub – and the relative shade tolerance of the desired trees versus the invasive species). For example, green retention within openings might be modified to increase or decrease shade, or reduced to limit the 'scaffolding' for invasive vines. It is also a new requirement within the permit for timber harvesting that all equipment must be cleaned and inspected by a DWSP forester prior to being brought onto DWSP property in an effort to limit the transport of invasive seed or vegetative propagules from offsite onto DWSP watersheds.

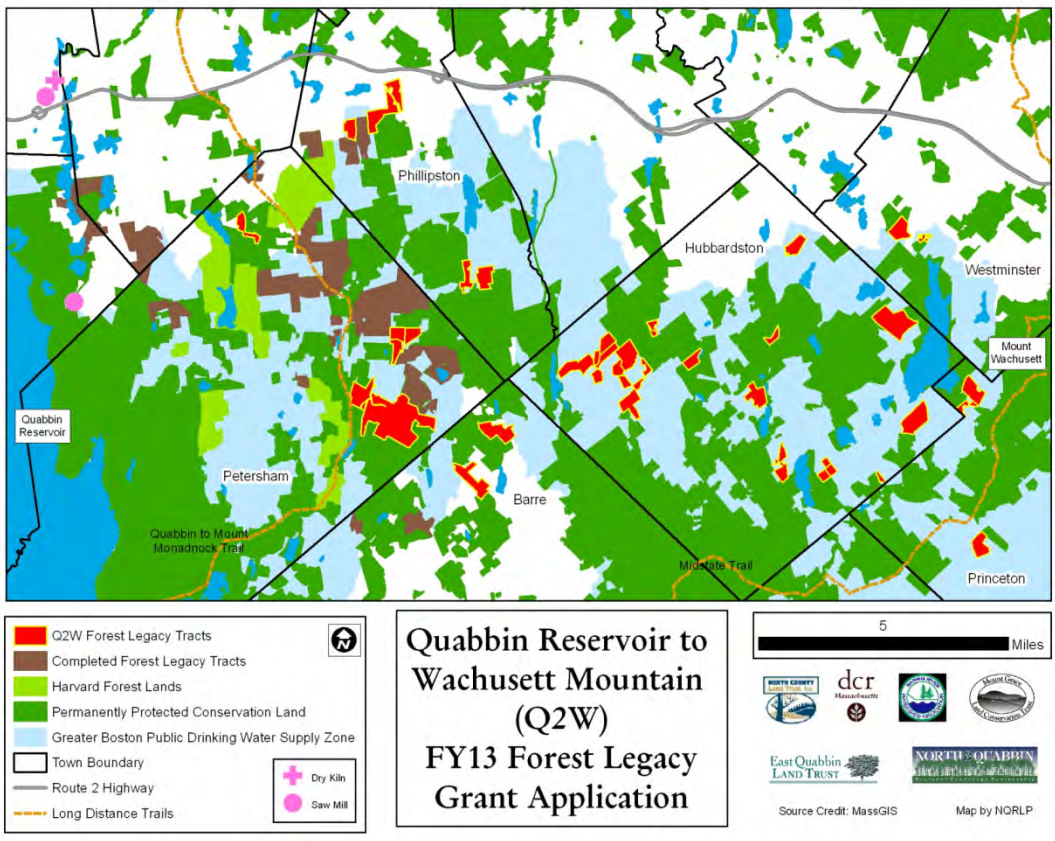
4.8 Strengthening source water protection within the Wachusett Reservoir watershed

The DCR Division of Water Supply Protection's Watershed Protection Program provides a drinking water source of exceptionally high quality. DWSP is committed to the goal of maintaining and enhancing the level of water quality for future generations. In order to achieve this goal, DWSP has developed a comprehensive set of programs to control water quality threats identified by ongoing assessments. There are four overarching concepts that guide the DWSP control programs: 1) Protect the most sensitive areas of the watershed through ownership or agreements with land owners; 2) Manage DWSP-owned properties to protect water quality and provide stewardship of natural resources; 3) Work with watershed communities to protect water resources while accommodating community needs; 4) Monitor to identify potential or existing water quality problems. The Watershed Protection Plan details a five year strategy of system-wide goals and watershed specific objectives, while Annual Work Plans enumerate tasks to be accomplished in each watershed. DCR recognizes the importance of local land use and public works decisions on the entire system's water quality; DCR staff have shared their expertise and resources with the watershed towns on zoning bylaws, master planning, gull and beaver control, wastewater infrastructure, hazardous waste disposal, and storm water management.

Land acquisition, through both fee acquisition and Watershed Preservation Restriction (WPR) purchases, is a core component of DCR's Watershed Protection Program. Since the late 1980s, DWSP has spent over $130 million, funded by MWRA ratepayers, to purchase parcels that were identified utilizing GIS and professional staff analyses based on water quality factors. This acquisition strategy, which emphasizes the Wachusett Reservoir watershed due to its limited protected conservation property, has successfully raised DWSP ownership in that watershed from 8% to 28% over the past twenty years. Critical acquisitions have also been made in the Quabbin Reservoir and Ware River watersheds, both of which already had significant areas under DWSP control; these two western watersheds have lower land prices as well as less forest fragmentation, providing DWSP the opportunity to permanently protect large parcels of forests and fields from development.

The $135 million authorized by the 1992 Watershed Protection Act for DWSP acquisitions is nearly depleted. MWRA, however, is moving toward including a minimum of $5 million in new funding in its capital budget for the next five years. Future acquisitions will continue to focus on the Wachusett Reservoir watershed, though DWSP will still pursue high value projects in the Quabbin Reservoir watershed and limited properties within the Ware River watershed.

DWSP is also working closely with other organizations to share costs, leverage acquisitions, accept gift land donations, and obtain federal funds. DWSP hopes to be the recipient of a major Forest Legacy acquisition grant if the highly rated "Quabbin to Wachusett" Forest Legacy application receives funding. The project, valued at $8,375,000, will place Watershed Preservation Restrictions on 3,275 acres of land held by 23 landowners on parcels across the northern portions of the Quabbin Reservoir, Ware River, and Wachusett Reservoir watersheds (see map below). DWSP is working with seven towns, four land trusts, and one watershed association to complete this project.



5. Glossary of Terms

Basal area: The cross section area of the stem or stems of a plant or of all plants in a stand, generally expressed as square units per unit area. Tree basal area is usually calculated at 4.5 ft about the forest floor (for convenience in measuring), and is used to determine percent stocking. For example, if a stand of white pine of a given age is considered fully stocked when there are 150 square feet of basal area in white pine trees per acre, then 75 square feet of basal area per acre would be considered 50% stocked.

Green retention: Trees are retained in a variety of silvicultural systems (e.g., seed tree harvests, shelterwood regeneration cuts), but typically not beyond the desired maximum age of the stand (in forestry, this is known as the "rotation"). "Green" retention also involves leaving either single trees or aggregated groups of trees - for control over regeneration via shade and seed production, for wildlife habitat features, or for aesthetics - but is distinct in that the length of time during which these trees will be retained is indefinite. Green retention is generally retained beyond the rotation age and may be left to biological maturity (i.e. until the trees die of natural causes).

Irregular shelterwood: "Regular" shelterwood systems, which are even-aged silvicultural systems, involve preparatory thinnings that begin to regenerate the stand, followed by a series of overstory removals that allow the development of trees that tolerate midrange levels of understory light, and the final removal cut at the end of the rotation or maximum desired age of the stand. "Irregular" silviculture differs in that it retains stocking, as individuals or aggregated groups, for much longer than the usual rotation age. As a result, the stand develops a more diverse, multiple age-class structure, which can have advantages for a variety of purposes, including watershed protection.

Silviculture: Similar to agriculture, the simplest version of silviculture is weeding, thinning, and harvesting to produce desired forest products. However, a broader definition is to apply the principles of *silvics* (life history, growth, behavior, and ecology of trees and forests) to accomplish both the commodity and the non-commodity objectives of the landowner for a forest that is under management. Silviculture is frequently defined as both the science and the art of working with the variation within the forest to modify and improve its ability to meet the desired purposes, such as the protection of drinking water supply, or the production of recreational opportunities, wildlife habit, income, or combinations.

Turbidity: This measure of water quality assesses the level of transparency or opaqueness resulting from the relative concentration of materials suspended in the water. Most turbidity measurement systems use the passage and reflection of light as surrogates for the direct measurement of suspended solids, which may be organic or inorganic. Standards require turbidity to be measured soon after a sample is taken, because delays can result in algal growth that will give false readings.

Weirs: There are lots of uses for weirs, from water storage to fishing, but a measuring weir is simply an overflow structure built perpendicular to an open channel to measure the discharge or rate of flow of water. By forcing the full volume of the stream channel through an opening with a fixed shape (e.g., a 120 deg V-notch), the discharge at any time can be calculated by measuring the height of the water in that opening. Combining discharge (volume per unit time) with water quality concentrations (e.g. nitrogen or total suspended solids, in mg/liter), the annual contribution to the downstream reservoir (a.k.a. "loadings") of sediments or other potential pollutants can be estimated.