Quabbin Reservoir, MA: Monitoring Watershed Forests Using CFI—1960-2000

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The 410 billion gallon Quabbin Reservoir was built during the 1930s to meet the growing demand from metropolitan Boston for drinking-quality water. An extensive watershed forest was acquired surrounding Quabbin for water quality protection. Early forestry efforts revolved around reforesting the fields surrounding the four towns that were disincorporated prior to construction of the reservoir, and salvage efforts following the 1938 hurricane. More directed silviculture began in earnest in the 1960s. During his tenure as Forest and Park Supervisor for the Quabbin forest, Fred Hunt recognized the potential value of installing a Continuous Forest Inventory (CFI) system at Quabbin. The intent was to periodically gather information on the condition of the forest, and to use it to guide the improvement of both water protection and forest management values on the watershed.

Hunt initiated the field work to install CFI plots at Quabbin in April 1960. Plots were established on a ½ mile grid that was laid out over topographic maps, and then located in the field by plotting bearings and distances on the maps from known, identifiable locations (e.g., road intersections). All CFI plots are 1/5 acre in size (52.66 feet in radius), each plot representing 160 acres of the watershed forest. Plot center was marked with a hardwood stake. "Witness trees," from which bearings and distances to the center stake were recorded, were identified and marked, so that the center could be relocated if the stake disappeared.

Plot information collected in 1960 included:

—Town
—Principal use of the area consistent with water production
—Cause of the most recent disturbance of the area and the year in which this occurred
—Timber type group based on the Massachusetts Cooperative Wildlife Research Unit Forest Cover Type Maps prepared from aerial photographs taken in 1952
—Type, size, and density of timber on the plot
—Size and number of principal tree "weeds" growing on the plot
—Silvicultural work needed on the plot and the timeframe for completion
—Relative ease or difficulty in harvesting the timber
—Reproduction count by species on 10 milacre plots nested within the larger plot

Information was gathered from 347 CFI plots established in 1960, representing 55,520 acres of watershed forest lands. All softwoods 9.0" in diameter at breast height (dbh) and above and all hardwoods 11.0" dbh and above were measured to the nearest 1/10th of an inch. Tree number and a permanent point for measuring dbh were painted on the tree. On a random sample of all plots, all trees greater than 5.0" dbh were measured in order to sample younger growing stock. The following data were recorded for each tree that was sampled:

—Plot number
—Tree number
—Species
—Dbh to nearest tenth of an inch
—Best product that could be harvested from the tree
—Merchantable height
—Percent of sound volume
—Quality and vigor
—Management recommendation for this tree
—Cause of any defect or past damage to the tree

In 1960, 31% of the forest was in stands dominated by white pine, with an average volume of 3,300 board feet per acre and 39% of the forest was in oak types, with 1,800 board feet per acre. Birch/red maple stands covered 17% of the forest, hemlock covered 4%, and the rest was divided among a wide variety of minor upland and wetland forest types. Hunt detailed his findings in his master's thesis (Hunt, 1961). Below are a few highlights from that document:

> Stands younger than 20 years old occupied less than 8% of the forest; stands older than 60 years old were estimated to occupy even less.
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> Sawtimber on the 55,520 acre forest totaled an estimated 127,065,000 board feet, of which 40% was white pine and 26% was oak. Current value of all sawtimber was estimated at $1,346,889 based on an average stumpage value of $10.60 per thousand board feet. Poletimber was estimated to total about 260,000 cords.
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> The Chestnut blight and the hurricane of 1938 resulted in two-storied stands of sawlog residuals above smaller trees, on a total of about 17,000 acres.
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> 65% of the sawtimber trees, by volume, were rated as good to excellent in vigor. Just 2% of the sawtimber trees were rated as "dying."
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> Metal was found in about 1% of the total sawtimber by volume, ranging from old fence wire to railroad spikes and horseshoes.
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> The white pine weevil was rated as the most damaging of the biological agents affecting the forest, while white pine blister rust and gypsy moth were determined to be well under control. Dutch elm disease was finishing off most of the remaining elm trees.
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> Regeneration (trees 3 feet tall to 4.9" dbh) averaged 254 stems per acre, but some areas, and the Prescott Peninsula in particular, showed no regeneration of valuable species during the previous fifteen years because of deer browsing (hunting was prohibited).
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> Annual growth of sawtimber was estimated to be about 4.7 million board feet.

Bruce Spencer became Head Forester at Quabbin in 1965, and immediately remeasured the plots. The majority of Quabbin silviculture from 1965 through 1990 was improvement cutting, with the exception of conversions of red pine plantations back to fields in the 1980s to increase water yield. The CFI plots were well-marked, but were intended to be, and have been treated exactly as the surrounding forest is treated. Spencer remains as Head Forester today, and he and his staff have remeasured the CFI plots at least once every decade. Additional data were collected each time, so that the current measurement standards include a full measurement of all trees greater than 5.5" dbh, and nested sub samples of saplings and regeneration. Azimuth and distance from the plot center is now recorded for each tree over 5.5" dbh, to enable plot reconstruction following natural or deliberate disturbances. In the 2000 remeasurement, plot data included:

—Administrative block
—Slope in one of three broad categories
—Aspect
—Land use
—Disturbance
—Year of disturbance
—Wildlife/insect/disease present in or damage to overstory
—Overstory type
—Silviculture needed
—Regeneration interference
—Invasive plants present

Data collected in 2000 on each tree included:

—Tree number
—Azimuth – true bearing from plot center
—Distance from plot center (using sonar measuring device)
—Species
—DBH
—Status (repeat, new, standing dead, fallen, cut)
—Crown class (dominant, codominant, intermediate, suppressed)
—Total number of 8 foot sticks to 4 inch tip
—Number of 16 foot sawlogs to 8-10 inch tip
—Total tree height for 2-3 dominant trees
—Product potential (sawlog, fuelwood, pulpwood, wildlife, cull, dead)
—Potential (preferred crop tree, acceptable, unacceptable, dead)
—Wildlife value (mast, cavities, cover)

While timber volume is a secondary driver on this watershed protection forest, CFI has enabled managers to track volume changes that result from silvicultural practices. During the forty years from 1960 to 2000, based on CFI plots, it is estimated that the 55,500 acre Quabbin forest increased in total estimated volume from 127,065,000 board feet at Hunt's original measurement to 527,300,000 board feet in Spencer's most recent (2000) measurement, an increase of approximately 400,000,000 board feet, net of timber harvesting. Periodic annual net growth of sawtimber was therefore 181 board feet per acre. This compares favorably to the statewide average annual net growth of 148 board feet per acre (USDA Forest Service FIA data for 1985 to 1998), and attests to the value of deliberate silvicultural management. Approximately 1,000 timber harvests occurred during this same time period, removing 130 million board feet. Natural mortality averages 0.4 to 0.8% of stocking per year. Periodic annual increment, including harvested volume and net of natural mortality, was approximately 240 board feet per acre from 1960 to 2000. Table 1 details the net change in standing volumes.

Species	BF 1960	% of Total	BF 2000	% of Total	Change in % of Total
White pine	50,920,000	40.1	230,058,000	43.6	+3.5
Hemlock	11,914,000	9.4	39,265,000	7.5	-1.9
Red pine	1,398,000	1.1	23,806,000	4.5	+3.4
Other softwoods	1,574,000	1.2	5,316,000	1.0	-0.2
Sugar maple	2,134,000	1.7	5,783,000	1.1	-0.6
Red maple	7,544,000	5.9	27,799,000	5.3	-0.6
Red oaks	32,544,000	25.6	144,714,000	27.4	+1.8
White oak	7,001,000	5.5	14,151,000	2.7	-2.8
Yellow birch	1,427,000	1.1	4,107,000	0.8	-0.3
Black birch	2,331,000	1.8	12,402,000	2.3	+0.5
Paper birch	858,000	0.7	3,576,000	0.7	No change
White ash	2,650,000	2.1	13,459,000	2.6	+0.5
Other hardwoods	4,759,000	3.8	2,864,000	0.5	-3.3
TOTALS	*127,065,000*	*100*	*527,300,000*	*100*	

Table 1: Estimated volumes, 55,500 acre Quabbin Forest, 1960 and 2000.

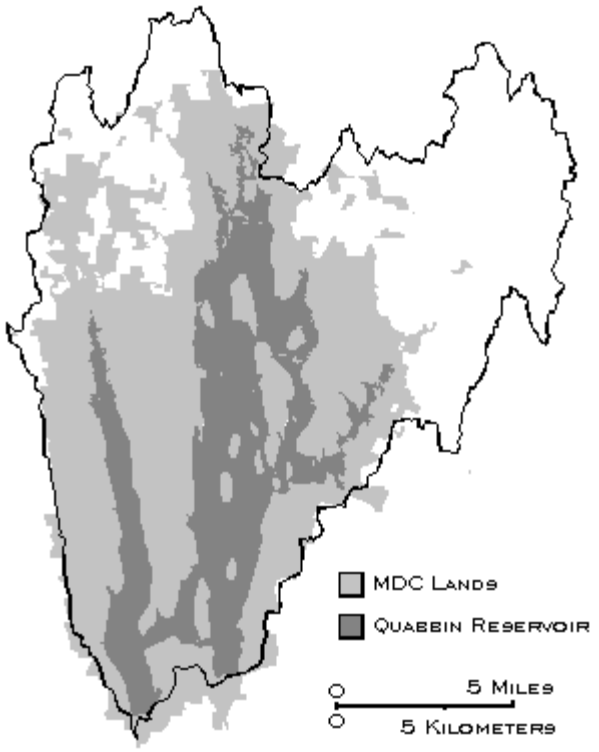
Management plans for Quabbin have focused on creating the optimum forest structure for this watershed protection forest, a structure composed of diverse species and age classes. The absence of regeneration, first noted in Hunt's CFI analysis, led eventually to a controlled public deer hunt that has continued since 1991 (Dizard, 1999) and has successfully restored the understory. Measurements taken recently capture this change but the 2000 CFI also shows a gap in the sapling size class representing the missing generation of trees that vanished during fifty years of hunting prohibition.

In regeneration plots taken across the forest on an annual basis since 1989, the change in regeneration is dramatic. In 1989, within areas of the Quabbin forest outside the Reservation and therefore continuously hunted (deer numbers were approximately 8-10 per square mile), regeneration 1 foot tall to 1 inch dbh averaged 3,100 stems per acre. Inside the Reservation, where deer numbers approached 60 per square mile following fifty years with no hunting, regeneration averaged 910 stems per acre, and the vast majority was either white pine or black birch, two species far down the list of preferred deer browse. Furthermore, regeneration taller than 4.5 feet inside the Reservation averaged just 10% of that outside the Reservation, and was virtually absent on large areas. As shown in Table 2, regeneration within the Reservation recovered dramatically once hunting began again in 1991. While saplings below 5.5" dbh were not measured in earlier years, CFI measurements in 2000 showed despite regeneration improvements, saplings from 1" to 5.4" dbh were still twice as abundant off-Reservation (628 per acre) as on-Reservation (336 per acre), so that the missing generation has not yet been fully replaced.

Area	Year	1' to 4.5' tall	4.5' tall to 1" DBH	TOTAL
Off Reservation (continuously hunted)	1989	1,960	1,140	3,100
	2004	2,071	1,404	3,475
On Reservation (hunting began 1991 after 50 year prohibition)	1989	770	130	910
	2004	3,187	1,344	4,531

Table 2. Regeneration changes in the Quabbin forest.

Like the improvement in regeneration following the initiation of deer population control, much of what has been learned from repeated CFI measurements simply confirms predicted results. Pioneer species, such as pin cherry, grey birch, and poplar, have been steadily declining as this forest matures. The impacts of gypsy moth infestations during the 1980s are visible; oak mortality rates, not including harvesting, were 5% (red oak) to 18.5% (black oak) from 1980 to 1990. The arrival of fungal control of gypsy moth infestations is also apparent, as just 0.6% of red oak and 2.5% of black oak died between 1990 and 2000.



Maturing softwood stands contain 3-4 times the volumes of hardwood stands. The overall average sawlog volume has grown dramatically from 2,300 bf per acre in 1960 to 9,350 bf per acre in 2000. Some softwood stands currently carry in excess of 35,000 bf per acre. The fastest growing individuals are white pine with one or more sides of the crown fully exposed. The slowest growth occurs on ridge tops with thin soils and in species capable of withstanding low moisture for long periods (e.g., black oak).

In addition to the original Hunt report on Quabbin CFI, results are reported as a component of each 10 year renewal of the Quabbin Land Management Plan (MDC, 1995). The collection of these data is labor intensive, requiring "all hands on deck" for the forestry staff once every ten years, for several months. Nonetheless, the successful "green" certification of this forest in 1997, the arrival of new insect pests and increasingly troublesome invasive plants, and general public demands for greater accountability for the effects of management will likely force the expansion of Quabbin's CFI to include a broader array of variables. We anticipate taking advantage of more sophisticated mensurational tools, in particular to improve estimates of product and total heights, and greater use of improved remote sensing to strengthen the accuracy of predictions based on these sample plots. The Quabbin CFI data set is one of the longest continuous records in the New England forests, and the current plan is to continue to remeasure it at least once every ten years.

References

Dizard, J.E. 1999. Going wild: hunting, animal rights, and the contested meaning of nature. Revised/expanded 2nd edition. University of Massachusetts Press, Amherst, MA. 230p.

Hunt, F. M. 1961. Forest resources on Metropolitan District Commission lands surrounding Quabbin Reservoir. M.S. Thesis. Department of Forestry and Wildlife Management, University of Massachusetts, Amherst. 128p.

MDC. 1995. Quabbin watershed land management plan 1995-2004. Public document produced by the Massachusetts Metropolitan District Commission, Division of Watershed Management (now the Department of Conservation and Recreation, Division of Water Supply Protection).183p. Note: the 2005 revision currently being prepared will include a review of the 2000 CFI remeasurement.