A Comprehensive Forest Conservation Plan for Long-term Watershed Protection on the City of Baltimore's Reservoirs

Prepared by:
State of Maryland
Department of Natural Resources
Forest Service

for the
City of Baltimore
Department of Public Works

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Introduction

Purpose

The City of Baltimore owns and manages the Loch Raven, Prettyboy, and Liberty reservoirs, located north and northwest of the City, in the northern Piedmont region of Maryland. These reservoirs supply water to over 1.8 million people. The watersheds, which are the primary source of water supply for the reservoirs, are located in Baltimore, Harford, and Carroll Counties in Maryland, as well as York County, Pennsylvania. City-owned land makes up only an average of 7 percent of the total area of the watersheds draining into each reservoir. These source water drainages are part of the urbanizing, and expanding, Baltimore - Washington metro area which is the fourth largest in the U.S. The Prettyboy and Liberty basins, however, are still rural in character with agricultural use predominant.

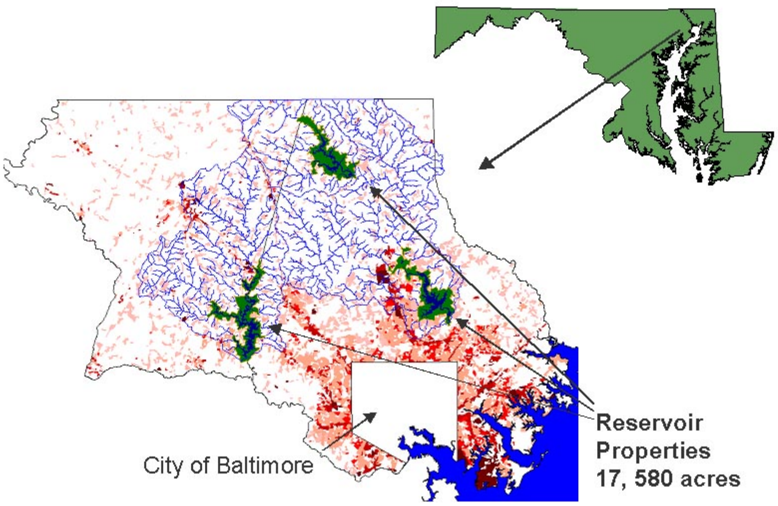

Figure 1 Location of Reservoirs

Preserving the quality of the water that flows into the reservoirs requires careful control of sediment as well as point and non-point source pollutants. To protect this critical regional resource the City acquired 17,580 acres of forested land surrounding the reservoirs between 1880 and 1955 to insure control of critical areas immediately adjacent to the reservoirs.

In April 1999 the Maryland Department of Natural Resources (MD-DNR), Forest Service entered into an agreement with the City of Baltimore to develop a comprehensive Forest Resource Conservation Plan for the 17,580 acres of land surrounding the Loch Raven, Prettyboy, and Liberty Reservoirs. Through a cooperative agreement with the U.S. Forest Service, and the use of its NED-1 Decision Support Software (see appendix L), a detailed forest stand level analysis incorporating forest patch methodology was conducted. Data were collected on wildlife habitat composition and structure, and on the quality of habitat along first and second order streams. A recreational user survey was conducted to determine the types of active recreation taking place and their compatibility with the City's forest management goals.

Future Desired Condition

The City of Baltimore wishes its forest lands to be vigorous and diverse; actively regenerating at levels adequate to sustain the forest; nutrient assimilating and protective of water quality; deliberately patterned to allow specific forest community types to occupy their optimum sites; resistant to disturbances that would degrade water quality; and resilient, capable of restoring forest control of the land after large or intense disturbance.

Programmatic Goals – Forest Conservation

An explicit set of programmatic goals for conservation were set through a series of 20 public meetings conducted by the City of Baltimore's Department of Public Works, during 1991. These goals included:

1. The protection and enhancement of water quality,
2. The maintenance and restoration of regional biological diversity within the public lands surrounding the reservoirs,
3. The management of woodlands to maximize forest habitat value, and
4. Providing recreational opportunities compatible with the above objectives.

These goals are hierarchical and exclusionary. Goal #1 is to be completely addressed before considering any of the following three. All actions to address goals 2 through 4 must not degrade the value of the forest to achieve the protection and enhancement of water quality.

Scientific Basis for Management

The broad Programmatic Goals set by the City Department of Public Works require a holistic approach to management. Such a management system must strive to maintain basic ecosystem functions and processes. An ecosystem approach to management is best understood as an expansion of natural resource management and human-land relationships in three dimensions: time, space, and degree of inclusion (Meffe and Carroll 1997). In 1995, the Ecological Society of America published their report, “The Scientific Basis for Ecosystem Management” (ESA 1995). The report emphasized details of the ecological basis for ecosystem management and identified eight essential components:

1. long-term sustainability,
2. clear operational goals,
3. sound ecological models and understanding,
4. understanding complexity and interconnectedness,
5. recognition of the dynamic character of ecosystems,
6. attention to context and scale,
7. acknowledgement of humans as ecosystem components, and
8. commitment to adaptability and accountability.

With complex issues it is useful to find a touchstone. We can do this by going back to the basics of applying ecological principles to guide management. With this in mind the eight guiding principles of ecosystems management set forth by the Ecological Society of America were used as the framework for evaluating operational goals and objectives and management recommendations. To assure continuity, all programmatic goals, operational goals and objectives, and the management recommendations for the next ten years were indexed to the eight principles of ecosystem management.

During the development of this plan numerous scientists and natural resource management experts were consulted on topics specific to their areas of expertise. In addition, a large body of scientific literature was reviewed (see appendix R), which served to guide the planning process from start to finish, assuring that the plan is solidly founded on the best scientific understanding.

Change is the normal course for ecological systems. Changing physical and biological conditions, the changing needs of society and changes in scientific understanding require the ability of the City to adapt its management strategy, without sacrificing long-term sustainability as an overarching goal. Such adaptation requires a system to monitor the physical and biological aspects of the forests, but also the need to review the latest scientific insights into ecological understanding that provide guidance for the natural resource managers. The plan addresses both these aspects of an ecosystem approach to management by requiring the establishment of a monitoring system (see appendix K) to evaluate not only implementation, but the effectiveness of conservation practices. The plan also requires the establishment of a Science and Technical Advisory Committee (see appendix N) to review new management challenges and provide advice on management assumptions and models used for planning. The practice of adaptive management will require flexibility and willingness to change as new information becomes available.

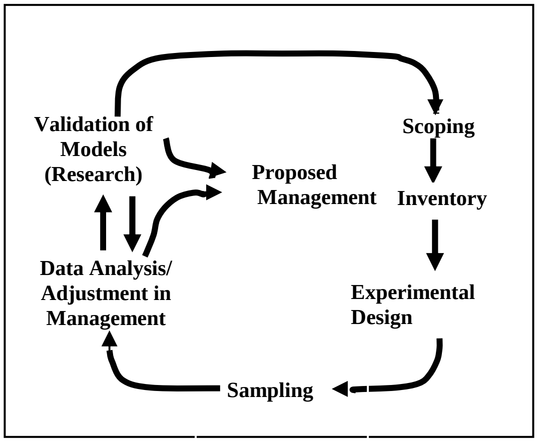

Figure 2 Adaptive management

An ecosystem-based approach to management has been adopted, in various forms, by numerous organizations, including state agencies and the U.S. federal government. Michael Dombeck, former director of the U.S. Forest Service, and Christopher Wood (1997) published an essay describing the use of ecosystem management on public lands and identifying the nine ‘operating principles’ of ecosystem approach:

1. Sustain the productivity and diversity of ecological systems,
2. Gather and use the best available scientific information as the cornerstone for resource allocation and other land management decisions,
3. Involve the public in the planning process and coordinate with other federal, state, and private landowners,
4. Determine desired future conditions based on historical, ecological, economic, and social considerations,
5. Minimize and repair damage to the land,
6. Adopt an interdisciplinary approach to land management,
7. Base planning and management on long-term horizons and goals, and
8. Reconnect isolated and fragmented parts of the landscape.

Forests and Watershed Protection

Numerous studies of watersheds have provided evidence that forest ecosystems provide the best protection for water quality (Carlton 1990; Dunne and Leopold 1978). The health of streams, rivers, and reservoirs is tied to the dynamic well being of the forest. The forest system, including the plants, animals, non-living elements, and their structures are intimately associated with ground and surface water quality and flow patterns. The maintenance of a diverse, multi-layer forest capable of resistance to major disturbances, such as ice and windstorms, and resilient to minor disturbances provides an efficient and effective means of protecting drinking water quality.

Through the continuous maintenance of a forest cover, soils are protected from erosion by:

1. Absence of overland flow,
2. Protection of erodible mineral soil by a thick layer of organic material,
3. High water holding capacity of the organic matter mixed with the upper soil horizon,
4. Dissipation of the energy of rain drops through the interception of canopy and mid-story trees and shrubs,
5. Reduction of the amount of rainwater reaching the ground due to interception by trees and shrubs (2-6% of flood-producing rainfall and 5% of the 40-45 inches of annual precipitation common in the eastern United States),
6. Increased water storage of the forest soil due to reduced transpiration rates during the growing season (18 inches of the 40-45 inches of annual precipitation common in the eastern U.S.); reduced flood damage due to structural protection afforded by riparian forests, and
7. Capturing sediment moving onto the reservoir lands from off site.

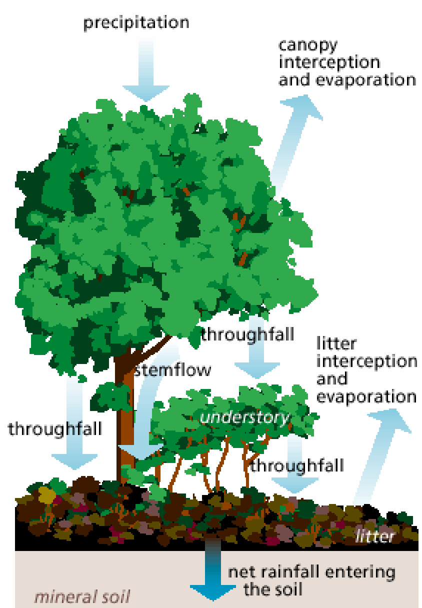

Figure 3 Forest watershed protection

Forests also capture a variety of elements and materials that would otherwise be deposited into the streams and reservoirs. These forest systems provide a line of defense against atmospheric deposition of heavy metals and acids and intercept groundwater pollutants entering the reservoir lands from off site and physically and chemically transform these pollutants to render them harmless.

Forest cover reduces stream and soil temperatures which helps by slowing down chemical processes that can release nutrients associated with water quality degradation and the production of by-products that degrade water and habitat values.

Forest Inventory and Key Findings

Forest Inventory

The City's interest in the long-term sustainability of the forest lands led to the selection of an inventory system that would provide data associated with both the biotic and abiotic attributes of the forest lands. These data will serve as the baseline for long-term monitoring of the plan's effectiveness in achieving the City's goals. A total of 2500 understory and 1500 overstory-sampling units were taken on the properties.

Specific data were selected to provide the ability to analyze forest conditions in small homogenous groups known as stands, larger units and patches with a variety of shrub and tree species, to the watershed level to allow for the inclusion of off site problems and opportunities associated with forest management and water quality. The intensity of the inventory was set to meet federal planning criteria confidence levels for forest planning in the eastern United States.

Forest types, size classes, and relative position within the landscape were used to initially stratify the forestlands. An initial field review of forest plant community types and sizes led to the mapping of 836 different stands**.** Each stand was sampled using standardized sampling methods.

Key Findings

1. The forestlands contain 14 different types of forest plant communities (maps 2, 7, 12).
2. While seedlings and young trees would be expected on all of the 2500 understory plots, they were found on only 25%. The level of seedlings was far below accepted standards and puts the ability of the forest to perform its function of protecting the water resource at serious short-term and long-term risk.
3. The inventory revealed only low levels of herbaceous (25%), shrub (18%) and understory trees (58 ft to lowest canopy) in plots. This lack of a multi-layering of vegetation reduces the ability of the forest to intercept rainfall and protect soil from erosion and to prevent sediment moving into the streams and reservoirs.

Table 1 Percent ground cover

Liberty		Loch Raven		Prettyboy	
Pine	Hardwood	Pine	Hardwood	Pine	Hardwood

Mean		31%	31%	25%	33%	27%	25%
Standard Deviation		15%	18%	17%	19%	13%	15%
Range	Low	0%	0%	0%	0%	0%	0%
	Median	29%	26%	22%	30%	22%	22%
	High	68%	85%	60%	90%	70%	80%

Table 2 Percent shrub cover

		Liberty		Loch Raven		Prettyboy	
		Pine	Hardwood	Pine	Hardwood	Pine	Hardwood
Mean		22%	25%	12%	18%	23%	19%
Standard Deviation		17%	15%	12%	13%	12%	16%
Range	Low	0%	0%	0%	0%	0%	0%
	Median	18%	25%	10%	16%	21%	18%
	High	80%	70%	44%	60%	60%	78%

Table 3 Height to canopy

		Liberty		Loch Raven		Prettyboy	
		Pine	Hardwood	Pine	Hardwood	Pine	Hardwood
Mean		56.6 ft.	64.2 ft.	53.1 ft.	60.1 ft.	49.3 ft.	58.9 ft.
Standard Deviation		12.4 ft.	16.8 ft.	18.0 ft.	18.3 ft.	11.4 ft.	16.7 ft.
Range	Low	29.0 ft.	15.0 ft.	6.0 ft.	0.0 ft.	30.0 ft.	0.0 ft.
	Median	57.0 ft.	64.0 ft.	51.0 ft.	60.0 ft.	47.5 ft.	61.0 ft.
	High	93.0 ft.	100.0 ft.	97.0 ft.	112.0 ft.	79.0 ft.	94.0 ft.

4. Deer browse pressure is the principal reason for the lack of adequate seedling, small tree and shrub representation in the understory.
5. The forest is even-aged, with trees of the same size predominating. This lack of a diversity of trees of various ages and sizes does not provide an assurance of a renewable forest in the face of small or large-scale disturbances that lead to tree death.

Table 4 Age and size class distribution of forest

AGE CLASS	SIZE CLASS	LOCH RAVEN	LIBERTY	PRETTYBOY

1-30 years	1”-5” dbh	1%	0%	4%
31-60 years	6”-12” dbh	6%	7%	15%
61-90 years	13”-19” dbh	57%	81%	79%
90+ years	20”+ dbh	36%	12%	2%

6. GIS analysis indicated that 30% of the forest community types were growing away from the optimum sites that are best suited to their long-term productivity and vigor (map 17).

Habitat Inventory

Wildlife usually responds to forest structure as well as to the plant species. While the forest inventory provided the information on forest plants, structure (including living and non-living parts of the forest) needed to be inventoried to provide a description of the various habitats found on the City forestlands. For instance, water sources which include temporary (vernal) ponds, permanent streams, and spring seeps provide critical habitat for amphibians; loose soil can be easily burrowed into; rock piles and rock crevices can be used by small mammals and reptiles; while mammals, amphibians and reptiles all use caves. The number of dead and dying standing trees is critically important for birds and mammals which use these trees for food and shelter. The vertical differentiation of the various herb, shrub and tree canopies provides habitat needed by regional and migratory birds. The data were collected at the same time as the forest inventory.

The Department of Natural Resources – Natural Heritage Data Base was reviewed with the help of experts in botany and zoology to determine if there were any species of plants or animals living on the properties that were rare, threatened, or endangered.

Key Findings

1. Upper level forest canopy was well represented (see table 5), but other elements of vertical layering of vegetation, including herbs, shrubs, understory trees, and midstory trees were not available for habitat use.

Table 5 Canopy closure

		Liberty		Loch Raven		Prettyboy	
		Pine	Hardwood	Pine	Hardwood	Pine	Hardwood
Mean		75%	63%	57%	57%	71%	50%
Standard Deviation		13%	14%	19%	18%	15%	20%
Range	Low	41%	10%	0%	0%	30%	0%
	Median	77%	63%	60%	58%	70%	53%
	High	100%	100%	90%	100%	99%	90%

2. Reservoir forests provide more riparian habitat, 1340 acres (7.6% forest), than typical of the regional watersheds**.**
3. The plantations of conifers, including white pine, Virginia pine, pitch pine, red pine and loblolly pine (30% forest) provide a dense protective habitat cover that is a component of the region's forest habitats.
4. The search of the Department of Natural Resources – Natural Heritage Database identified several species of concern along the reservoir fringe, but none within the forestlands.

5. Each of the properties contain areas of uncommon habitat that are of conservation interest and that enhance regional biological diversity.
6. The forested areas surrounding Loch Raven and Liberty reservoirs support reproducing pairs of bald eagles.
7. A GIS analysis of forest edge indicates a total of 2466 acres of forest interior, contained in 292 separate patches.
8. Snags, dying or dead standing trees, were found within 43% of the forest units. Snags would be expected to be found in all units across the forest.
9. Coarse woody debris, dead limbs and logs on the ground, were found at an average rate of 48 cubic feet per acre. The total accumulation of this important habitat component is high for the forest's age and size, though the diversity of coarse woody debris sizes was dominated by branch and limb sized pieces, lacking the larger forms contributed by fallen trees (see appendix D).

Stream Habitat

All streams for each of the three properties were identified using a USGS map and given a unique identification code. Fifty percent of the streams for each property were randomly selected to be surveyed. For each of the streams selected, a 400-foot transect was walked within the boundaries of City reservoir property. Along the transects, key habitat features from the Maryland Biological Stream Survey were collected along with an adapted version of Rosgen's (1996) bank erosion potential index. The habitat features surveyed were: amount of woody debris in and out of the water, number of rootwads in and out of the water, woody debris within the riparian buffer, trash rating, silt deposition, bar formation, number and species of exotic plants, stream character, land use, buffer breaks, and evidence of channelization.

Key Findings

When assessing the quality of a stream, the physical habitat is an important aspect to consider along with water quality and biological indexes. A good stream habitat contains four essential parts: a naturally vegetated buffer, naturally vegetated stable banks with meandering channels, a variety of substrates, and different water depths and velocities. Degradation of physical habitat is one of the most significant stress factors on the streams in Maryland. Currently only 20% of all streams in the state of Maryland have good physical habitat quality (EPA and DNR 1999). Less than 40% of the streams in both the Gunpowder River Basin (Loch Raven and Prettyboy) and the Patapsco River Basin (Liberty) are considered to have good physical habitat (EPA and DNR 1999).

Riparian forest buffers are an integral part of stream habitat. They are important for several reasons. Among these are providing woody debris and rootwads for shelter, detritus as a food source, and preventing bank erosion. Streamside trees also aid in temperature stabilization. The canopy prevents direct sunlight from hitting the water and thus prevents warming of surface waters (EPA 1995; Sweeney 1992). Even when the canopy does not cover the stream due to stream width, forests still play a role in keeping consistent water temperatures. By holding onto ground water longer, and thus increasing the time it takes ground water to reach the stream, it cools water entering into the stream system (EPA 1995). Statewide, only 59% of the total stream miles have forested riparian buffers (EPA and DNR 1999). The Gunpowder River Basin has just over 60% of its stream miles forested and Patapsco River Basin has approximately 50% of its stream miles forested (EPA and DNR 1999). Looking at those figures, each of the reservoirs provides a great service since all of the stream miles within the property boundaries are buffered with a forested riparian strip. The only breaks in the buffer for the streams surveyed were roads, both paved and unpaved.

Wood in streams is important on many levels. The most apparent benefit is the shelter it provides for both fish and benthic macroinvertebrates (EPA and DNR 1999; Sweeney 1992). Woody debris can also help with food supply. It dams up and holds detritus and can be used as a slowly decaying food source itself (EPA 1995). Once settled, woody debris works to stabilize banks and change water flow (EPA 1995; Sweeney 1992). By changing water flow, diversity in water depths and velocities increases, which increases the number of possible habitats (EPA 1995). Statewide, the approximate number of pieces of wood per stream mile is 91 (EPA and DNR 1999). The approximate number of pieces of wood per stream in the Gunpowder River Basin is 90, while the average for the Patapsco River Basin is about 75-80 pieces per stream mile (EPA and DNR 1999). The averaged results for the streams at each of the City's reservoirs are:

1. Liberty had 9 pieces per segment (approximately 117 pieces/mile),
2. Loch Raven had 14 pieces per segment (approximately 176 pieces/mile), and
3. Prettyboy had 10 pieces per segment (approximately 135 pieces/mile).

Rootwads extending beyond the water surface serve as fish shelter. The averaged results for in-water rootwads present per segment sampled at each reservoir are as follows:

1. Liberty had 3 rootwads per segment,
2. Loch Raven had 4 per segment, and
3. Prettyboy had 2 per segment.

The channelization of a stream is any artificial straightening of the stream channel (EPA and DNR 1999). When a stream channel is straightened the speed of water flow increases (EPA and DNR 1999). As the speed of water increases, the rate of erosion increases and the diversity of water velocities decreases (EPA 1995). Seventeen percent of the stream miles in the state of Maryland are channelized (EPA and DNR 1999). The only artificial straightening of streams within the City property were incidental with bridge construction. This is consistent with the streams within the Gunpowder River Basin while 25% of the stream miles within the Patapsco River Basin are channelized (DNR 1997; DNR 1998).

Streams with a good overall physical habitat have stable banks due to a high number of tree roots, logs, rocks, etc. (EPA and DNR 1999). Unstable banks, or banks with a high potential for erosion, lead to increased sediment loads in the stream. The Gunpowder River Basin has approximately 50% of its stream miles with a high potential for erosion while the Patapsco has about 60% (DNR 1997; DNR 1998). Using a modified version of the Rosgen (1996) index, a stream is considered to have a high potential for bank erosion with scores between ten and twelve. All of the streams surveyed had scores indicating a high erosion potential. The index results were as follows:

1. Liberty – 10.0,
2. Loch Raven – 11.6, and
3. Prettyboy – 10.3.

The amount of bar formation within the segments sampled at Liberty and Loch Raven was another indicator of sediment loads and bank erosion potential. Fifty percent of the segments sampled at Liberty and thirty-eight percent of the segments sampled at Loch Raven had extensive bar formation. Prettyboy had only minor to moderate bar formation.

Internal Roads Inventory

Roads can adversely impact water quantity and quality. Runoff from the forest floor in the eastern United States is minimal. The surface of woodland roads provides a smoother and less resistant path than the forest floor for rainfall and snowmelt movement, and leads to an increase in the rate and volume of runoff. Improperly designed and maintained road surfaces, drainage structures, and culverts provide the highest risks for sediment loading. Sediment can impact water quality by increasing turbidity and by carrying chemical pollutants such as phosphorus, pesticides, and hydrocarbons.

The City was uncertain of the condition and length of its system of unpaved internal forest roads. These roads provide access for emergency response to human injury and wildfire suppression, conservation activities, and recreational activities.

The roads were mapped using a geographic positioning system (maps 3, 8, 13). At the same time an assessment of the condition of the road surface, proper drainage, and an inventory of all road/water conservation practices, such as stream culverts, fords, bridges, drainage breaks, etc., was undertaken. Each of the road's conservation management practices was rated based upon:

1. placement: where feature is located,
2. condition: physical shape of feature, and
3. installation: how feature was constructed.

Key Findings

1. The reservoir lands contain 213 miles of internal low-volume roads. (Note: this is a larger road system than used by the City of Boston's reservoir system, which is over 60,000 acres.)
2. The road system covers 387 acres.

3. Drainage problems were identified along the majority of the road system, with 40 stream culverts rated as being in poor condition, stream fords with silt substrates, and bridges that were unsafe or missing.
4. The field inventory of the internal road system also led to the identification of numerous instances of trespass activities that degraded the road systems and/or led to the deterioration of the forest with consequences for the degradation of water quality:
    a. Dumping of debris and hazardous materials,
    b. Cutting, removal, and damage of trees and plants,
    c. Disturbance or removal of soil and ground cover,
    d. Paving or covering of soil and ground cover,
    e. Grading or filling land,
    f. Installation of fences, and
    g. Construction of sheds, signs, tree houses, and stream obstructions.

Recreational User Survey

The City of Baltimore, Department of Public Works, the Friends of the Watersheds, and the Maryland Department of Natural Resources all provided information as to what recreational groups fairly constitute "stakeholders" for the reservoir areas. Organized stakeholder groups and the appropriate agencies were contacted to obtain mailing lists for inclusion in the study. These groups included bird watchers from the Baltimore Bird Club (approximately 440 members); mountain bikers from the Maryland Association of Mountain Bike Operators (MAMBO) (approximately 550 members); horseback riders from Trail Riders of Today (TROT), Plantation Walking Horses of Maryland, and Carroll County Equestrians (members living near reservoir areas estimated at 250); and boat permit holders for all three reservoirs (roughly 900 in all). Hunters were included as an additional stakeholder group in the spring of 2001 at the request of the Maryland DNR. There are 3005 hunting permit holders for the Prettyboy and Liberty reservoirs. Once mailing lists were obtained, names were randomly selected from each list, except for the birders (the Baltimore Bird Club provided a list of randomly selected members).

Other data collection methods included the distribution of postcards at the reservoir areas and to residents living adjacent to the reservoir areas.

Data were gathered using a seven-page mail questionnaire (appendix M). The first page of the questionnaire included an introduction and a map of the study area along with questions about frequency of visits to each reservoir area. The questionnaire focused on identifying recreational use patterns, views on resource management issues, awareness of management initiatives, and general demographic information. The survey mailing included a pre-notification letter; an initial questionnaire with cover letter, including postage paid return envelope; a follow-up postcard reminder; and a second "replacement" questionnaire with cover letter and postage paid return envelope.

During this time the Baltimore Ecosystem Study (Long-Term Ecological Research Project, funded by the National Science Foundation) conducted a telephone survey of Baltimore City and County residents. A portion of this survey was used to acquire information on preferences for outdoor recreation. These data sets are being correlated to a demographic trend analysis of U.S. Census data and the Recreational User Survey conducted on the City reservoir lands by the U.S. Forest Service, Northeastern Research Station. The result will be a description of expected trends in the type, frequency, and location of recreational use.

Key Findings

1. Survey respondents were asked which reservoir location they consider to be <u>the primary location</u> that they visit for recreation.

	Loch Raven	**Prettyboy**	**Liberty**
All survey respondents	60%	19%	21%
Mountain Bikers	89%	6%	5%
Birders	80%	8%	12%
Boat Permit Holders	49%	34%	18%
Horseback Riders	21%	21%	59%
Hunters	8%	20%	72%

2. <u>Top four issues perceived as **moderate to serious problems** by</u>

Land-based recreationists:	*Water-based recreationists:*	*Hunters:*
Littering (51%)	Littering (59%)	Littering (41%)
Lack of other recreation opportunities (32%)	Soil Erosion (22%)	Lack of other recreation opportunities (28%)
Use of motorized vehicles (27%)	Lack of other recreation opportunities (21%)	Conflicting uses (24%)
Soil erosion (26%)	Vandalism (18%)	Dumping of household trash (18%)

3. <u>Top four issues perceived as **not a problem** by</u>

Land-based recreationists:	*Water-based recreationists:*	*Hunters:*
Human waste (80%)	Hiking off woods roads (89%)	Timber

		harvesting (99%)
Timber harvesting (75%)	Timber harvesting (84%)	Dogs in the water (98%)
Hiking off woods roads (73%)	Overcrowding of woods roads (81%)	Safety and security (97%)
Loitering (73%)	Human waste (79%)	Hiking off roads (96%)

Operational Goals and Objectives

Forest Management – Silviculture

The primary focus of the first 10 years of management is the re-establishment of adequate levels of seedling regeneration, reduction of the high risk of disturbance to pine plantations from large storms, and the development of structural complexity and diversity. These steps require a significant reduction in seedling browse by the deer herd and the use of silviculture to provide space for seedling development.

For the purpose of organizing conservation management practices to reduce risk to the long-term sustainability of the forest, the three properties were mapped according to their most appropriate long-term uses consistent with the City's four programmatic goals. These mapped "management areas" include:

"Natural management" sites where implementation of silviculture (following the establishment of adequate levels of natural regeneration) will be restricted to the enhancement and protection of important habitats, mitigating immediate threats to water quality, the control of invasive and exotic plants and animals, and other emergencies (maps 1, 6, 11).

Natural management areas include:

1. Riparian – all lands within 100 feet of streams or reservoirs,

2. Natural Areas – specifically designated areas for the development of native plant seed banks and long-term monitoring, and
3. Steep Slopes – soils on slopes greater than 25%, which are highly susceptible to erosion.

“Uneven-aged silvicultural management” sites where implementation of an uneven-aged silvicultural system leads to reduction in risk to water quality and /or a long-term benefit to the conservation of local and regional biological diversity (maps 1, 6, 11).

Uneven-aged silvicultural management areas include:

1. Pine plantations at high risk for wind-throw from large storms (map 16),
2. Shallow soils (maps 5, 10,15),
3. Shallow soils associated with off property sources of pollutants, and
4. General - all other sites not covered by the preceding categories.

The long-term use of uneven-aged silvicultural management will be centered on low rates of harvest (less than the 1% naturally occurring mortality rate for the eastern deciduous forest) using group selection and reserving six trees per acre from harvest for long-term seed and debris production. Goals differ by management area.

Pine plantations at high risk for wind-throw: These areas presently include 1330 acres of Virginia pine along the southwestern shore of the Prettyboy Reservoir. Their age (45-60 years), shallow root systems and the open fetch from the northeast make them highly susceptible to wind-throw. They will be systematically regenerated to a more wind-resistant native hardwood forest community through the use of an irregular strip shelterwood system .

Shallow soils associated with off property sources of pollution: These sites will be physically determined in the field following the maps provided through this project. They will be managed to optimize vigorous pollutant assimilation. Regeneration cycles will approximate 80 to 90 years.

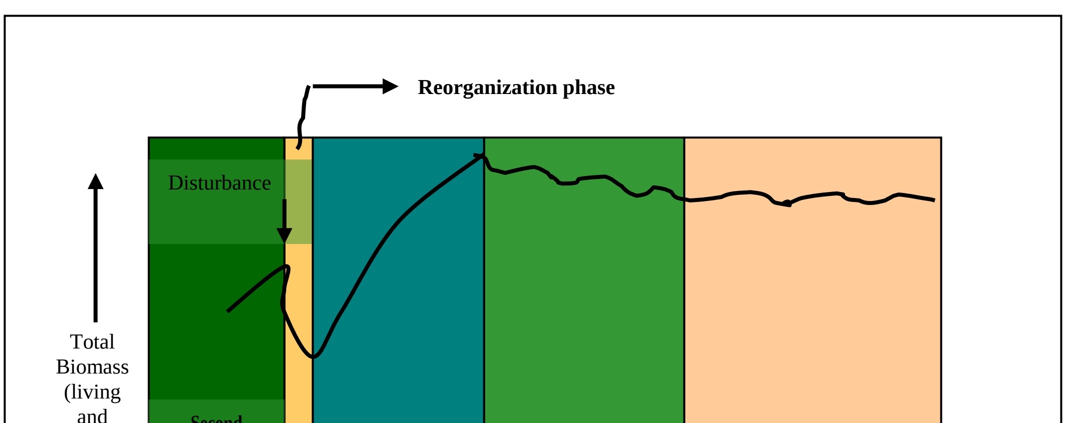

Figure 4B: Biomass vs. time

General area: These areas contain moderate to deep soils and are not associated with active sources of pollution from off property land uses. They will be managed to maintain forest community health through the maintenance of species and structural diversity and forest tree vigor. Regeneration cycles will approximate 130 years, with retention of specific trees that will reach 200 years or older before cutting.

Forest Management - Other Measures

Implement the City’s preferred deer control strategy – essential to the long-term sustainability of the forestlands.
Reduce sediment moving off the internal road system. Sediment reduces water quality and is the major source of phosphorus moving into the reservoirs.
Reduce the immediate human impacts to soil, vegetation, wildlife habitat, and water quality through:

- Registration of all recreational users
- Active and passive education
- Law and regulation enforcement
- Controlling access

Forest Protection

Protection Goals (Operational Goals)

1. Limit reservoir forest land uses to those that do not threaten water quality, and
2. Control or minimize non-forest land use (e.g., roads), the impacts of extensive and intensive deer browse, the effects of natural events (e.g., extreme weather, fire, ice/wind storms, etc.) and human activities that threaten water or other natural resources.

Protection Objectives (Operational Objectives)

1. Locate, mark, and maintain the boundaries of the reservoir lands. Clear boundaries allow for better control over illegal activities that threaten water quality. Effective resolution of boundary encroachments is also an integral part of boundary maintenance.
2. Increase the presence of the City's authority off road. The control of potentially harmful activities on reservoir lands requires a human presence to identify and locate those activities, and to provide effective enforcement of rules and regulations. This presence is provided by the City Watershed Police and maintenance crews, the State Police, and the DNR Police. This presence is intended to allow for the timely discovery and resolution of harmful human activities (e.g. illegal dumping) and natural events (e.g. fires) on the reservoir properties.
3. Effective land use monitoring and control depend upon a good road system that allows quick access to all parts of the reservoir lands. However, since these same roads can constitute a source of sediment, water quality should be protected through:
    a. Closure of roads in designated riparian zones and natural areas (25% of total road system),
    b. Removal of all debris which prohibits access to roads, and
    c. Retrofitting all culverts that are identified as in poor condition.
4. Protect the forest from wildfire through a coordinated suppression and prevention program in association with the DNR Forest, Wildlife and Heritage Service and City, State, and local volunteer fire companies (appendix G).
5. Restrict access and use of natural areas and riparian areas through:

a. the use of gates,
b. designating restriction of use areas,
c. closing of areas due to weather,
d. permitting access and use,
e. law enforcement, and
f. prohibition of certain activities.

6. Reduce deer browse pressure upon seedling regeneration to establish adequate advanced regeneration necessary for the long-term sustainability of the forest.
   To account for varying seedling survival by height class, seedlings will be weighted as follows to determine adequate levels of regeneration on 1/100 acre plots:

Height	Weight
2 inches to 1 foot	1
1 to 3 feet	2
3 to 5 feet	20
5 feet and larger	50

   Any combination of weighted stem that meets or exceeds the minimum number required is considered stocked. Tree seedling densities are presented for favorable and unfavorable expectations of developing a canopy tree for every 1/100 acre plot. For conditions of low deer density it is assumed that 25 seedlings per 1/100 acre plot will be sufficient. For high density areas it is assumed that 100 seedlings will be required (McWilliams 2000).

7. Eliminate the potential for large scale blow-down of the 1330 acres of Virginia pine plantations within the Prettyboy forest through the regeneration of a native forest type using the strip shelterwood silvicultural system (map 16) .

Forest Restoration

Restoration Goals (Operational Goals)

1. Restore native forest communities to sites presently occupied by pine plantations.
2. Restore specific forest types to sites which represent the optimum environmental conditions for the types.
3. Restore natural regeneration to levels adequate to quickly recover control of hydrology and nutrient cycling following an intense large-scale disturbance.

Restoration Objectives (Operational Objectives)

1. Use an uneven-aged silvicultural system to maintain a vigorously growing, soil protecting and pollutant assimilating forest cover. Typical stands will grow out to 130 years old containing reserve trees that reach over 200 years old (appendix O).
2. Use an uneven-aged silvicultural system to establish a more vigorously growing and pollutant assimilating forest cover on shallow soils adjacent to known sources of groundwater pollution. Typical stands will grow out to 100 years old.
3. Establish shrub plant communities within all utility rights-of-way.
4. Establish 1400 acres of natural areas.
5. Restrict the use of silviculture (except for water quality protection) within the 100-foot riparian zones along the streams and reservoirs to enhance and protect habitat values.
6. Protect the forest from human induced disturbances by:
   a. Initiating a wildfire policy to enhance and coordinate City, State and local volunteer fire company suppression activities;
   b. Actively restricting access to and use of sensitive areas through the use of gates, designation of restricted use areas, the closing of areas due to weather, use permitting, law enforcement, and prohibition of certain activities; and
   c. Systematically maintaining and enforcing property boundaries.
7. Establish a Science and Technical Advisory Committee of experts in natural resource and watershed management to suggest approaches to solving new or evolving problems.
8. Use an uneven-aged silvicultural system to create and maintain the structural

diversity and complexity needed to directly influence habitat, regulate nutrient cycling, and the hydrologic cycle. (Structural diversity and complexity includes standing dead trees, logs and woody debris, multiple canopy levels and canopy gaps.)

Long-term Forest Conservation

Forest Conservation Goals (Operational Goals)

1. Maintain a vigorous and diverse (composition and structure) forest.
2. Maintain the forest cover by assuring adequate natural regeneration of seedlings.
3. Maintain a forest that achieves active growth, nutrient assimilation, water infiltration, and regulation of soil and stream temperatures.
4. Prevent sediment and nutrients from entering the streams and reservoirs.
5. Provide for the active assimilation of nutrients and other pollutants entering the City properties from adjacent land holdings.
6. Limit the effects of atmospheric pollution through the filtering and buffering of pollutants.

Long-term Forest Conservation (Operational Objectives)

1. Monitor the implementation and effectiveness of all management practices based upon established indicators.
2. Use an uneven-aged silvicultural system to maintain an aggrading forest cover within the active management zone.
3. Use an uneven-aged silvicultural system to maintain a more vigorously growing and pollutant assimilating forest cover on shallow soils adjacent to known sources of shallow groundwater pollution.
4. Maintain a shrub plant community within all utility rights-of-way.
5. Maintain approximately 1400 acres of natural areas as source sites for the natural regeneration of all forest plants and as control sites for the monitoring program.
6. Continue the restriction of active management (except for water quality protection, habitat restoration, etc.) within the 100-foot riparian zones along the streams and reservoirs to enhance and protect this important habitat.
7. Protect the forest from wildfire through a coordinated suppression and prevention program in association with the DNR Forest, Wildlife and Heritage Service and City, State and local volunteer fire companies.
8. Actively restrict access and use of natural areas and riparian areas through the use of gates; designating restriction of use areas; closing of areas due to weather; permitting access and use; law enforcement; and prohibition of certain activities.
9. Systematically maintain and enforce property boundaries.
10. Establish a Science and Technical Advisory Committee of experts in natural resource and watershed management to monitor basic assumptions and models used for decision making, and to provide an efficient way to gather the latest scientific information associated with new and evolving forest conservation problems.
11. Obtain Green Certification for the conservation plan and on-going

management.

12. As available, acquire adjacent properties and parcels within the watersheds identified by the DNR Forest Service, Wildlife and Heritage Service, and the MDE as posing a high risk to water quality.