Massachusetts and Rhode Island - Main Report and Appendices

Volume 1 of 2

Blackstone River Watershed Reconnaissance Investigation

August 1997

US Army Corps
of Engineers
New England District

Executive Summary

This Reconnaisssance Report documents the results of an Army Corps of Engineers investigation into restoration of the ecological environment of the 475 square mile Blackstone River watershed, located in south-central Massachusetts and northern Rhode Island. The report's primary purposes are to assess the watershed's problems, determine if there are actions appropriate for the Corps to take (i.e. identify the Federal interest) relative to environmental restoration in the basin, provide examples and costs of proposed actions, and determine the interest of potential sponsors in cost-sharing further, more detailed, investigations.

Congress has already recognized the national significance of the Blackstone River watershed, designating it a National Heritage Corridor in honor of it being the "birthplace of the American Industrial Revolution". However, significant ecological damage accompanied this industrial development. The river and its tributaries were extensively dammed for water storage and hydropower purposes, changing the aquatic environment from that of a free-flowing river to a string of warm water impoundments connected by short stretches of free-flowing river. Treated municipal and industrial wastewater continues to be discharged to the watershed. Although the widespread practice of the dumping of untreated municipal and industrial wastes into the basin's waterways has ceased, millions of cubic yards of contaminated sediments remain in the impoundments of the Blackstone. The sediments tend to become resuspended during high flows, impacting water quality, and eventually washing into, and degrading, habitat in Narragansett Bay, Rhode Island.

The report describes the resources of the Blackstone River basin and its ecological problems, which were determined to be the loss and degradation of the basin's wetlands, riparian, and riverine and pond habitat, a lack of once-prevalent anadromous fish, and degraded water and sediment quality. Habitat historically has been destroyed by filling, encroachment, and channelization, and the habitat type has been altered with the construction of dams. Development pressures on the basin continue, however, and further habitat loss and degradation are expected to result. The potential failure of one or more of the basin's poorly maintained dams poses a threat to habitat in the impoundments created by the dams, and to the habitat of downstream wetlands, riverine, and pond areas when the accompanying washout of impounded sediments occurs. Similar habitat losses are also experienced when owners, fearful of liability, drain the ponds.

The ecological and human health risks from exposure to the contaminated sediments remains largely unassessed as does the impact of sediment resuspension on water quality in various river segments. Improvements in water quality due to point and non-point source control may be offset by the continued destruction or disturbance of the fish and wildlife habitat.

The Reconnaissance investigation identifies a broad array of potential solutions to address the basin's ecological problems and presents preliminary designs and cost estimates for example projects believed most applicable in the Blackstone River watershed. One of the best opportunities to achieve significant ecological improvement in the watershed is to improve habitat areas at the existing impoundments. The Corps, through coordination with Federal, State and local agencies, and citizen groups, selected the Fisherville Pond site in Grafton, Massachusetts, as a prototype restoration project. Two alternatives are presented for Fisherville Pond, primarily to restore and enhance waterfowl habitat. Alternative 1 involves stabilization of the dam, reconstruction of the outlet works, re-vegetation of degraded habitat areas, dredging of 2 acres of potholes in the wet meadow areas, and construction of a 200-foot riparian buffer on the eastern side of the pond. Alternative 1 would restore 9.1 acres of valuable lost waterfowl habitat and improve the quality of the remaining habitat in the impoundment area. The estimated cost of Alternative 1 is $1,100,000. Alternative 2 would expand on Alternative 1 by dredging 25 acres of wet meadow habitat to provide additional open water and emergent habitat. A range of costs are provided for Alternative 2 to reflect the uncertainty associated with the quality of the sediments in the impoundment. The cost of Alternative 2 without any capping requirements is $2,120,000. If future studies identify the need to cap the excavated material, the cost of the project increases to between $3,560,000 and $6,900,000, depending on the type of capping required.

The Reconnaissance investigation identifies the continued deposition of sediment as a significant problem affecting the watershed. One of the project features presented to address this problem is the construction of a sediment capture pond at an existing impoundment. The prototype sediment capture project presented in the report is Singing Dam in Sutton, Massachusetts, located several miles upstream of Fisherville Pond. The project would consist of initially dredging approximately 120,000 cubic yards of material. Depending on the effectiveness of upstream sediment control measures, the impoundment would require maintenance dredging perhaps every 5 to 10 years. The estimated cost of the project is $3,020,000. Dredging of the impoundment would greatly increase its ability to trap significant amounts of sediment and other pollutants during wet weather events. The project will also restore open water fisheries habitat in the impoundment behind Singing Dam. Removal of sediment at Singing Dam would, over the long-term, protect valuable fisheries and wildlife habitat at Fisherville Pond and at other downstream sites.

Wetlands restoration project alternatives are presented for the 41-acre Lonsdale Drive-In site located along the Blackstone River in Lincoln, Rhode Island. Two alternatives are presented to restore the former Drive-In and enhance fisheries and wildlife habitat. Alternative 1 involves the removal of the asphalt and gravel base of the former Drive-In to create about 15 acres of emergent marsh and open water habitat. Existing forested riparian habitat along the river would be preserved as much as possible. The estimated cost of Alternative 1 is $2,100,000. Alternative

2 would involve the creation of about 22 acres of grassland habitat with no restored wetland habitat. The estimated cost of Alternative 2 is $1,250,000.

The Reconnaissance investigation also identifies the restoration of anadromous fish as a goal for the Blackstone River watershed. Federal and State fisheries agencies have identified the need to construct fish passage facilities at the lower four dams to gain access to the first significant habitat area at Valley Falls Pond. The Corps provided funding to USFWS as part of this study to develop preliminary designs and cost estimates at these dams. The costs for providing both upstream and downstream fish passage facilities are $910,000, $245,000, $595,000, and $455,000 for Main Street Dam, Slater Mill Dam, Elizabeth Webbing Mill Dam, and Valley Falls Dam, respectively. The present worth of O&M and monitoring at the four projects is an additional $148,000.

In addition to the above described projects, the investigation also provides preliminary designs and cost estimates for a habitat restoration project at the former Rockdale Pond site in Northbridge, Massachusetts ($1,730,000), a wetlands restoration project at a gravel pit in Northbridge, Massachusetts ($581,000), a habitat restoration project at Rice City Pond in Uxbridge, Massachusetts ($4,580,000) and a stream restoration project at Beaver Brook in Worcester, Massachusetts ($2,780,000).

Implementation of the watershed restoration projects presented would result in a significant positive impact on the ecological health of the watershed. However, the construction of these projects does not represent the full extent of work required to fully restore degraded ecological conditions in the watershed. Construction of similar projects throughout the study area would be required to achieve the highest level of improvement. This Reconnaissance investigation identifies the need for a comprehensive analysis of the problems and opportunities of the entire watershed, including an assessment of the opportunities offered by each sub-basin, to develop and prioritize additional restoration projects in the watershed. These studies would be conducted as part of future Corps of Engineers Feasibility Investigations. The Feasibility Investigation would also refine the preliminary restoration plans for the projects presented in this report and identify potential Corps implementation of additional restoration projects in the watershed.

This report recommends that the Corps proceed to the Feasibility stage of analysis. The Reconnaissance Report proposes that the Feasibility Study undertake a comprehensive inventory of the entire Blackstone River watershed's ecological resources, definitively evaluate the ecological and human health risks posed by contaminated sediments, and assess the ecological and other values of individual dams. It is proposed that the very significant task of project formulation, prioritization, and selection of specific projects that the Corps and others should implement to improve and restore fish and wildlife values be undertaken during a watershed-wide Feasibility Study.

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I. INTRODUCTION

In November 1992, the U.S. Army Corps of Engineers, New England Division (now District) was requested by the States of Massachusetts and Rhode Island, with the support of the Blackstone River Valley National Heritage Corridor Commission (BRVNHCC), to investigate opportunities to restore the ecological health of the Blackstone River watershed, with a particular interest in restoring anadromous fish and improving waterfowl habitat. This initial request resulted in the Corps completing a Planning Assistance to States (PAS) investigation which developed the framework for a comprehensive plan to restore the river. The PAS study was completed in November 1994 and was accomplished through extensive coordination with Federal and state officials, local communities, and other interested citizen groups. As a result of the states' continued interest in restoring the watershed, the Corps initiated this Blackstone River Watershed Reconnaissance Investigation. The study significantly expands upon the work of the prior Corps PAS study and continues to rely on available existing information and input from state, local, and other Federal agencies active in the study area.

1.1 Study Authority

The Blackstone River Watershed Reconnaissance Investigation was performed under the authority provided in the September 12, 1969 resolution known as the Southeastern New England (SENE) resolution. This resolution by the Committee on Public Works of the United States Senate gives the Army Corps of Engineers the authority to investigate solutions for "flood control, navigation, and related purposes in Southeastern New England ..."

1.2 Study Purpose

The purpose of this document is to present the justification for recommending that the Blackstone River Watershed Restoration Reconnaissance study proceed to a cost shared feasibility study based on the Corps mission of Environmental Restoration as stated in the Corps Civil Works budget Guidance and described in EC 1105-2-210 entitled "Ecosystem Restoration in the Civil Works Program".

The Blackstone River watershed has a number of significant water resources problems which impact on the health and diversity of its ecosystem. These problems include: lost and degraded wetland habitat, particularly for waterfowl; lost and degraded riparian habitat; loss of anadromous fisheries; degraded lake and pond habitat; lost and degraded river and stream habitat; and degraded water and sediment quality, with contaminated sediments associated with historic dumping of contaminants by industry. Some of these problems and impacts are typical of those found in other urbanized watersheds in the northeastern United States. Increasing urban and suburban development in the watershed has led to degradation of environmental quality resulting from the loss or degradation of wetlands and other fish and wildlife habitat resources. The severity of the degradation in the mainstem Blackstone River is particularly severe due to the intense industrial utilization of the river.

This reconnaissance study examines the watershed's problems, determines potential solutions to the problems and their costs, determines a potential role for the Corps in the watershed, and assesses the interest of potential cost-sharing partners. Projects to achieve significant benefit to the watershed which are eligible for Corps implementation are recommended for further study in the next project phase, the Feasibility Phase.

1.3 Study Area

The Blackstone River basin has a drainage area of 475 square miles[1], with 335 square miles in south central Massachusetts and 140 square miles in northern Rhode Island. The Blackstone River begins in the southern part of Worcester, Massachusetts at the confluence of the Middle River and Mill Brook and flows southeasterly for 46 miles to the Main Street Dam in Pawtucket, Rhode Island (see Figure 1 - Base Map). Below the Main Street Dam is the tidal Seekonk River, which in turn flows south to the Providence River, a northern arm of Narragansett Bay.

Total fall of the river is 438 feet, with an average drop of 10 feet per mile. Roughly 84 percent of the Blackstone's length is within urban areas, including the major cities of Worcester, Massachusetts and Woonsocket, Rhode Island. Several tributaries of the Blackstone run through heavily urbanized areas. These include Mill Brook, and the Middle, Quinsigamond, Mumford, Branch, Mill, Peters and Abbott Run Rivers. The Blackstone River is the second largest freshwater source to Narragansett Bay, providing almost one-fourth of its freshwater input. Only

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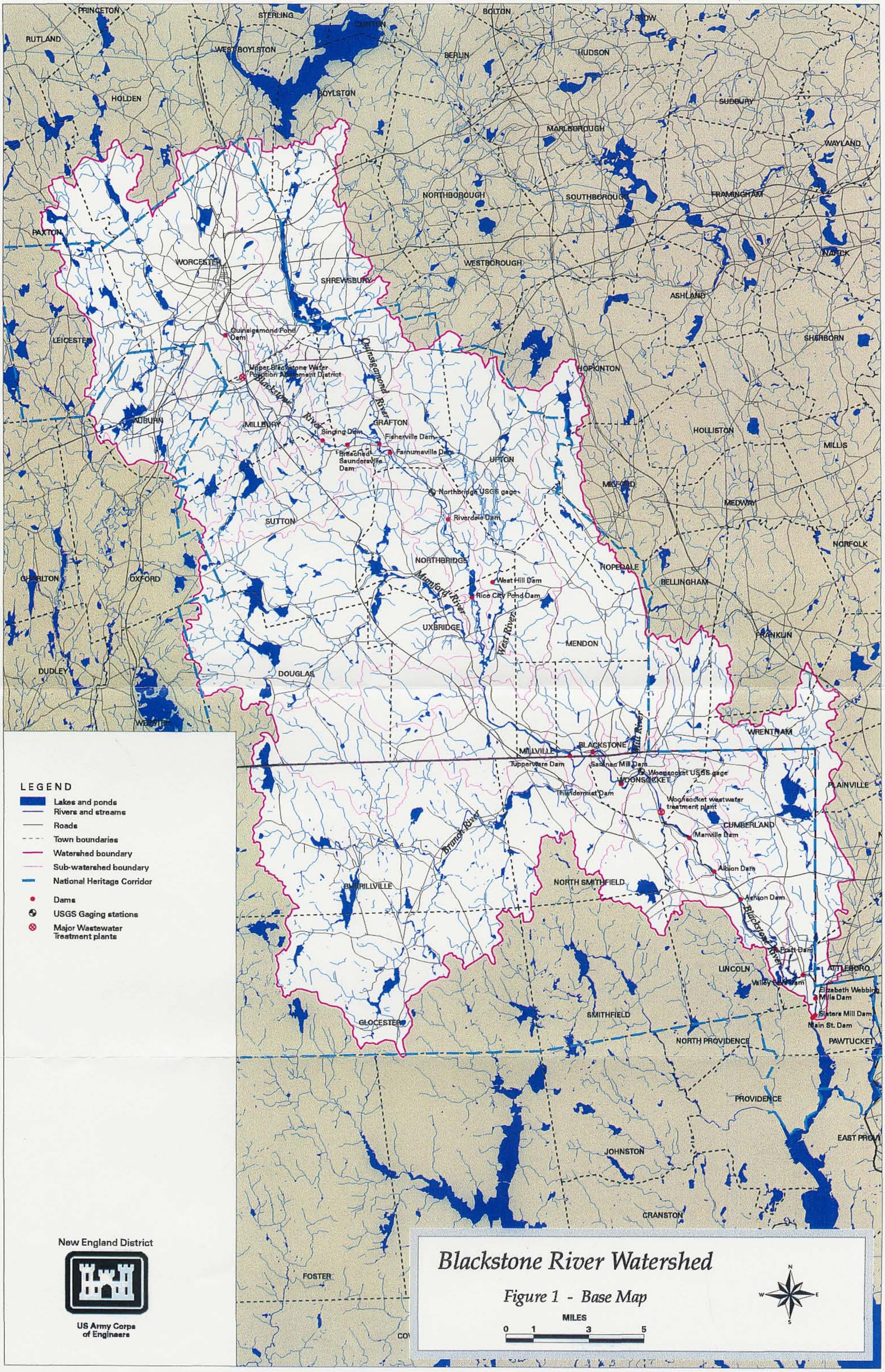
1 The drainage area for the Blackstone River differs from that cited in prior Corps reports. The 475 square-mile area is based upon Geographical Information System measurements that agree with values cited in US Geological Survey publications.



Blackstone River Watershed

Figure 1 - Base Map

17 dams and impoundments presently remain on the mainstem Blackstone of the "dam per mile" which reportedly existed at one time. Significant dischargers to the mainstem river include Worcester's Upper Blackstone Water Pollution Abatement District (UBWPAD) wastewater treatment plant (wwtp) and the Woonsocket wwtp.

1.4 Congressionally Designated National Heritage Corridor

The Blackstone River Valley is the birthplace of the American Industrial Revolution. In 1793, Samuel Slater established a water-powered textile mill in Pawtucket, Rhode Island marking the beginning of a new industrial way of life and its character. In recognition of its national significance, the U.S. Congress officially created the Blackstone River Valley National Heritage Corridor in 1986 as the nation's second National Heritage Corridor. It is a partnership park that stretches from the headwaters of the Blackstone in Worcester, Massachusetts to Narragansett Bay in Providence, Rhode Island. The heritage corridor effort is operated in conjunction with the Secretary of the Interior through the National Park Service, a National Corridor Commission representing the interests of the local communities, and several key state agencies from both Massachusetts and Rhode Island. The Corridor now includes 24 cities and towns and 400,000 acres.

1.5 Army Corps of Engineers Study and Implementation Process

This study was conducted at the reconnaissance level and was fully Federally funded. The reconnaissance study was performed to accomplish four tasks: (1) to identify problems, needs, and opportunities and potential solutions; (2) to determine whether more detailed investigations were warranted as part of a feasibility study, based on a preliminary appraisal of costs, benefits, environmental impacts, and consistency with Corps policies; (3) to develop an initial Project Study Plan (PSP); and (4) to assess the interest and capability of a non-Federal sponsor(s) to participate in a cost-shared feasibility study.

The reconnaissance study depended primarily on existing information and general site inspections. No detailed field surveying, mapping or subsurface exploration were accomplished for this investigation. When information was not available, suitable assumptions were made based on standard environmental and engineering practice. The information gathered was used to facilitate comparisons among alternative projects and plans in the preliminary decision-making process. Detailed comparisons of plans, design of project features, assessment of environmental impacts, preparation of plans and specifications, and construction of projects may be accomplished in project phases subsequent to the reconnaissance study.

1.5.1 Corps Four Step Study Process

The Army Corps of Engineers follows a four-step process for its Federal water resources projects. The planning process consists of two phases: a reconnaissance phase and a feasibility phase. The construction process also consists of two phases: the pre-construction engineering and design phase (PED), and the construction phase. The reconnaissance phase, which is this study's focus, utilizes existing information to analyze the water resources problems of the study area and to determine whether there is both Federal and non-Federal interest in further detailed investigations. As stated previously, the Reconnaissance Study is conducted at full Federal expense. During the subsequent feasibility phase, new data is collected and detailed analyses are performed to identify the best solution from economic, environmental, social, and engineering standpoints. The cost of the feasibility phase is shared equally between the Federal government and a non-Federal sponsor(s). The non-Federal sponsor(s) may include state, county, or local governments.

The following study process was used in this Reconnaissance Phase of the Blackstone River watershed study: (1) define existing conditions; (2) identify problems, needs, and opportunities in the study area; (3) identify potential solutions; (4) perform preliminary plan formulation, in which some alternatives are eliminated from further consideration; (5) identify alternatives to be considered in detail; (6) evaluate the potential impacts of each alternative; (7) estimate the alternative solutions' costs and benefits and determine whether one of the potential solutions is in the Federal interest; (8) identify a potential non-Federal sponsor for the potential solutions; (9) prepare a Project Study Plan (PSP); and (10) negotiate the feasibility cost-sharing agreement (FCSA). The PSP describes the tasks required during the feasibility study and corresponding costs. The FCSA lays out the management structure and financial obligations that both the Federal government and the non-Federal sponsor(s) agree to execute. This report contains a summary of the investigations, results, conclusions, and recommendations of this study process.

The feasibility phase will undertake more detailed examinations of solutions to identify environmental restoration opportunities within the Blackstone River watershed. The feasibility study process is complex, but can be summarized as follows: (1) prepare detailed design using new, updated information; (2) evaluate specific engineering, environmental, and economic effects; (3) identify the optimum project from both a Federal and non-Federal perspective; and (4) recommend one alternative for construction. If a project is recommended, the feasibility report would then be submitted to the U.S. Congress for project authorization.

The third and fourth phases are the PED phase and the construction phase. If Congress authorizes construction of the project, the final engineering and design are performed, and construction plans and specifications are completed during the PED phase. Actual construction follows the PED phase. The PED and construction phases are cost-shared 35 percent by the non-Federal sponsor and 65 percent by the Federal government.

1.5.2 Involvement By Others

Because of the limited time frame of the reconnaissance study, the public involvement process was primarily limited to governmental agencies familiar with the watershed. The Corps solicited input on both the types of solutions that should be implemented and specific areas needing improvements. Should the study move on to the feasibility phase, general public meetings would be held to obtain additional input into the project.

A reconnaissance investigation kickoff meeting was held with members of the U.S. Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (USFWS), the U.S. Geological Survey (USGS), the Natural Resources Conservation Service (NRCS), the Massachusetts Department of Environmental Protection (MADEP), the Massachusetts Department of Environmental Management (MADEM), the Rhode Island Department of Environmental Management (RIDEM), the BRVNHCC, the University of Rhode Island (URI), and others, attending. The purpose of the meeting was to provide an overview of the study process, explain what would be investigated in the Reconnaissance Investigation, summarize the Corps existing understanding of the watershed's problems, and solicit comments and input regarding the Corps understanding of the issues. The meeting also provided an opportunity to solicit input on the types of projects that the Corps should consider, and to solicit input into specific locations needing attention.

A 15-person technical advisory committee, consisting of members of EPA, USGS, Massachusetts Division of Fisheries and Wildlife (MADFW), RIDEM, BRVNHCC and URI, met to provide input to the Corps. The Corps received general concurrence from the committee that its proposed approach to the study of the watershed's problems, and the types of actions to be evaluated at prototype project locations was reasonable.

Other coordination meetings were held including one with EPA risk assessors to discuss approaches that the Corps should take concerning the basin's contaminated sediments, and more specifically those in Fisherville Pond. Meetings and field visits with representatives of various agencies were also held. In addition, periodic meetings of the BRVNHCC's Environmental Subcommittee Streamflow Task Force (attended by the EPA, USFWS, Rhode Island DEM's Division of Water Resources, MADEP's Office of Watershed Management (OWM, formerly the Division of Water Pollution Control), Massachusetts DEM's Office of Water Resources, the National Park Service, the Massachusetts Watershed Coalition, Massachusetts Audubon Society, University of Massachusetts Extension Service, and BRVNHCC staff) were regularly attended by Corps staff.

1.6 Prior and Ongoing Projects, Studies, and Reports

1.6.1 Flood Control Projects

The Army Corps of Engineers has constructed one flood control project, West Hill Dam, and four Local Protection Projects (the Worcester Diversion, and the Blackstone, Woonsocket, and Lower Woonsocket Local Protection Projects) in the Blackstone River watershed. Although design and construction of the Local Protection Projects (LPPs) was Federally funded, operation and maintenance of these projects was turned over to local governments. All of these projects were designed to reduce flood damages in the river basin. The following is a brief description of the projects:

West Hill Flood Control Project. Completed in 1961 by the Corps of Engineers, West Hill Dam is a flood control reservoir located on the West River, about 3.5 miles upstream of its confluence with the Blackstone River. This project is operated to control flood discharges from its 27.9 square mile drainage area. There is no seasonal or permanent pool at West Hill, however, the project does have 12,440 acre-feet of available flood control storage (equivalent to 8.3 inches of runoff).

Worcester Diversion Project. This project is located on Kettle Brook in Auburn and Millbury and was completed in 1960. It is comprised of a concrete control dam on Kettle Brook, a diversion structure, a 4,205-foot long tunnel, and an 11,000-foot long channel. The project diverts flood flows from 30.5 square miles of Kettle Brook to the Blackstone River, bypassing 7 miles of congested river channel in Worcester, thereby, reducing flooding within that reach.

Blackstone LPP. Completed in 1971, this 860-foot long earthen dike in the town of Blackstone, Massachusetts provides protection against flooding for the town hall, courthouse and residential and park areas.

Upper Woonsocket LPP. This project, completed in 1960, consisted of 8,300 feet of channel improvement with a trapezoidal channel section and stone slope protection, replacement of the Woonsocket Falls Dam (Thundermist Dam) with a new dam having four tainter gates, modification of two railroad bridges, a pumping station for a 44-acre interior drainage area, four dikes, a floodwall, and replacement of a highway bridge crossing the Blackstone River.

Lower Woonsocket LPP. This project consists of three units: Social District, Hamlet District, and Bernon. The Social District Unit includes 6 dikes, 3 floodwalls, excavation of 2 channels, 2 pressure conduits, and a pumping station. There are 1,100 feet of concrete T-walls on the Blackstone River averaging 13 feet high, 610 feet of concrete walls with an average height of 30 feet on the Mill River, and two channels totaling 610 feet. In addition, there are 1,870 feet of dike on the Blackstone, 2,410 feet on the Mill River, and 630 feet on the Peters River. The Mill River pressure conduit passes flows from a 34.7 square mile watershed, while the Peters River pressure conduit handles flows from a 12.7 square mile drainage area. The pumping station handles 284 acres of drainage area. The Hamlet District Unit includes three dikes totaling 3,100 linear feet with 75 feet of floodwall. The channel improvement is about 2,000 feet long. There is also a pumping station and gravity conduit. The Bernon Unit included the removal of Bernon Dam and 600 feet of channel improvements.

1.62 Shore and Bank Protection Projects

The Army Corps of Engineers has constructed one shore and bank protection project in the Blackstone River basin. The project is described as follows:

Blackstone River, Millbury. This project was constructed at the McCracken Road Bridge, about 2,000 feet downstream of the Massachusetts Turnpike. Large shoals (i.e. sandbars) in the center of the river were removed, and 300 feet of stone slope protection was constructed along each riverbank in order to protect the bridge structure.

1.6.3 Previous Corps of Engineers Studies

In the 1970's, the Army Corps of Engineers conducted a Reconnaissance Investigation of the Blackstone River watershed for the primary purpose of examining the flood control needs of the watershed (Ref. "Blackstone River Watershed", August 1981). The study investigated approximately 40 potential projects with only one, the Berkeley Local Protection Project, economically justified and warranting detailed study. Two alternatives were formulated for Berkeley, one structural and the other non-structural (flood warning/waterproofing), but neither was implemented due to financial limitations and lack of local support.

In November of 1994, a Planning Assistance to States (PAS) Program study by the Army Corps of Engineers entitled "Blackstone River Restoration Study" was published, providing the groundwork for this Reconnaissance Investigation. The PAS study identified problems of the mainstem Blackstone River, established objectives and a framework for their achievement, and noted that achievement of objectives would likely be a matter of tradeoffs. The problems and objectives were identified primarily through a number of meetings with Federal, State and community officials, private citizens, and environmental scientists, many of whom are continuing to contribute to this Reconnaissance Investigation.

1.6.4 Major Watershed Projects and Studies

In 1985, EPA created the ***Narragansett Bay Project (NBP)*** as part of its National Estuary Program. The NBP spent six years developing a plan to improve the Bay's quality of water, manage its living resources, and preserve its public uses. The "Comprehensive Conservation and Management Plan (CCMP) for Narragansett Bay" (EPA, NBP, RIDEM, and Rhode Island Department of Administration, Final Report, December, 1992) provides a blueprint for immediate and long-term actions to be taken by Federal, state, and local agencies and authorities well into the next century. Although the report cannot be considered a Blackstone River watershed report, the CCMP did identify the Blackstone River as one of two "Areas of Special Concern" due to its importance to the Bay and provided several recommendations specific to the Blackstone, including the development of a comprehensive sediment remediation plan with an estimated implementation cost of $144 million. No action has been taken to date on the recommended sediment remediation plan, other than a Massachusetts Section 319 bioremediation demonstration project at Rice City Pond in Uxbridge, Massachusetts (1997 implementation).

In 1990, EPA Region I organized the ***Blackstone River Initiative*** (BRI) at the request of the commissioners of the MADEP and RIDEM, in part due to the prompting of those involved with Rhode Island's Narragansett Bay Project and Save the Bay, a citizen's group. The BRI was established primarily to determine causes of the river's contamination and to facilitate future decision-making regarding pollution controls and abatement in the Blackstone River basin. Participants in the Initiative include EPA, MADEP's OWM, RIDEM, and URI. A major portion of the Initiative was to conduct dry weather and wet weather surveys of the river. The BRI's work includes an up-to-date comprehensive analysis of the toxicity and chemistry of ambient river water, sediments and their oxygen demand, sediment pore water, significant industrial and municipal water effluent, and a benthic macroinvertebrate community health analysis for several locations on the Blackstone River and selected tributaries. Fish tissue analysis performed by MADEP was also incorporated into the study.

The dry weather measurements are being used to determine the significance to the Blackstone River of tributary and point source discharges that dominate its water quality during low streamflows. The wet weather measurements are being used to determine the water quality impacts from stormwater runoff and the resuspension of contaminated sediment. This data, when coupled with streamflows, is being used to estimate dry weather versus wet weather loadings for several pollutants. Results of the Initiative were published in the April 1996 draft report entitled "Blackstone River Initiative: Water Quality Analysis of the Blackstone River Under Wet and Dry Weather Conditions".

A report entitled "A Sediment Control Plan for the Blackstone River" was published in July 1981 by the Massachusetts Department of Environmental Quality Engineering (DEQE, now DEP), Office of Planning and Program Management, documenting a major DEQE effort to address the issue of contaminated sediment at several Blackstone River sites and one tributary site, all in Massachusetts. The report, sometimes referred to as the McGinn report[2], described the levels of metals in sediment found by CE Maguire, Inc. in 1981[3], locations of sediment accrual, sediment volumes, impacts of the sediment on river ecology, and alternatives available to eliminate or mitigate the adverse impacts. The McGinn report also examined sediment quality guideline criteria developed for various areas/applications, previous Blackstone River water

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2 After its author, Joseph M. McGinn

3 "Bottom Deposit Removal and/or Control Alternatives for the Blackstone River", prepared by CE Maguire, Inc. for DEQE, March 1981

quality, sediment, and fish sampling studies, and attempted to assess the relative degree of contamination at each site using a "Sediment Pollution Index". The McGinn report recommended a comprehensive $35.6 million sediment management plan for the Massachusetts sites. None of the study recommendations were adopted.

1.7 Institutional Analysis and Ongoing Programs

1.7.1 U.S. Environmental Protection Agency

The EPA is currently awaiting the final BRI report results. It appears that EPA actions are focused on the point- and non-point sources of water quality degradation. EPA is working with the states to further tighten the NPDES permit limits of Blackstone River dischargers through the establishment of Total Maximum Daily Loads (TMDLs) for various water quality constituents in non-attaining river segments. EPA personnel have also been working with the BRVNHCC Environmental Sub-Committee Streamflow Task Force to require the Federal Energy Regulatory Commission (FERC) to eliminate the hydropower induced flow fluctuations on the Blackstone River by enforcing the existing license requirements that the plants operate as "run-of-river". EPA also provided comments to the Corps on the preliminary risk assessment done for Fisherville Pond as part of this Reconnaissance Investigation.

1.7.2 Massachusetts Executive Office of Environmental Affairs

Positive interest in the Reconnaissance Investigation and the direction it was taking was expressed in meetings of September 18, 1996 and April 22, 1997 between the Corps of Engineers and an EOEA representative.

MADEP's OWM has been highly involved in the Blackstone River Initiative, playing a major role in formulating and implementing BRI efforts. OWM has selected the Blackstone watershed as one of the first four watersheds in which TMDLs will be developed.[4] Both point and non-point loads are to be allocated as part of the TMDL process, which includes a re-opening of NPDES permits.

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4 Draft Blackstone R. Watershed - Resource Assessment and Management Plan.

1.7.3 Rhode Island Department of Environmental Management

Positive interest in the Reconnaissance Investigation was expressed in meetings of September 12, 1996 and April 3, 1997 with the state's Division of Fish and Wildlife, the agency designated by RIDEM as the point-of-contact for all Blackstone River study coordination. Particular interest was expressed in Corps proposals to restore the wildlife/wetland values of the Lonsdale Drive-In, Lincoln, Rhode Island and abandoned gravel pits, and the implementation of fish passage facilities at the lower four dams on the Blackstone River.

RIDEM staff are working with the BRVNHCC Environmental Sub-Committee Streamflow Task Force in its work with FERC to eliminate the water level fluctuations caused by the hydropower facilities.

RIDEM also has the Narragansett Bay Program which spearheaded much of the effort resulting in EPA's BRI.

1.7.4 Natural Resources Conservation Service

The Natural Resources Conservation Service currently has a relatively limited role in the watershed. NRCS has proposed the construction of a water control structure to be located immediately upstream of Lackey Pond Dam on the Mumford River sub-basin. The purpose of this structure is to insure that the very important waterfowl habitat provided by Lackey Pond not be eliminated by failure of the currently unsafe dam. The water control structure would serve as a dam. The dam itself will not be altered by NRCS as it has no authority to work on this historic dam.

1.7.5 U.S. Geological Survey

The U.S. Geological Survey (USGS) currently maintains several streamflow recording gages, two of which are on the mainstem Blackstone River, and several water quality gages in the watershed. The USGS also sporadically performs water quality monitoring at various locations.

1.7.6 Blackstone River Valley National Heritage Corridor Commission

The BRVNHCC has been pursuing a wide range of activities, from implementation of a bicycle trail along the full length of the Blackstone River to the opening of visitor centers to "signing" the basin. The BRVNHCC often works with Federal and state agencies, communities, political entities and other local interest groups to facilitate preservation and restoration activities in the corridor.

1.7.7 U.S. Fish and Wildlife Service

The USFWS has played a significant role, working with the BRVNHCC Streamflow Task Force, to encourage FERC to eliminate the hydropower-caused streamflow fluctuation. The USFWS is also working with FERC on the problem of dewatered reaches caused by hydropower diversions.

1.7.8 Massachusetts Audubon Society

The Advocacy Department of the Massachusetts Audubon Society in Worcester, Massachusetts has focused most of its efforts on water resource protection in the Blackstone River watershed. It strives to raise the level of awareness of the connection between land use and water quality in its work with citizens, local and state officials, and students. Programs include the Blackstone River Watershed Education Project, where over 400 students and teachers from 20 high schools throughout the watershed test the waterways three times a year, then gather to present their findings and create watershed-related projects for their communities. Massachusetts Audubon Society has published "Guiding growth and Development in Massachusetts - A Citizens' Handbook for Shaping the Future of Your Community", with an edition specifically tailored to Central Massachusetts and the Blackstone watershed.

1.7.9 Blackstone Headwaters Coalition

The Blackstone Headwaters Coalition is a partnership of nearly forty organizations, governmental agencies and individuals who are working together to address water resource protection and restoration issues in the Headwaters Region of the Blackstone River Watershed. The coalition's vision is of a Blackstone Headwaters Region that is as well-known for the beauty, health and recreational opportunities of its water resources as for its historic industrial contributions.

1.7.10 Sierra Club, Rhode Island Chapter

As part of its Blackstone River Valley Wetlands Restoration and Protection Campaign, the Sierra Club is identifying wetlands that may be particularly valuable to restore or protect. Sites identified by Sierra Club include: the Lonsdale Drive-In site, Fisherville Pond in Grafton, Massachusetts, the Cherry Brook/Cedar Swamp in North Smithfield and Woonsocket, and the stone and gravel mining site, Mendon Road, Cumberland, Rhode Island.

1.7.11 Other Entities

Many other non-profit entities are extensively involved in environmental restoration aspects in the watershed including Save the Bay, the Blackstone River Watershed Association, and Friends of the Blackstone.

II. EXISTING CONDITIONS

2.1 Physical Setting

2.1.1 Location

The Blackstone River basin, located in south-central Massachusetts and northern Rhode Island, is generally elongated in shape, with a length of about 46 miles and an average width of 12 miles. The total drainage area of the watershed is 475 square miles, 335 square miles in south central Massachusetts and 140 square miles in northern Rhode Island. The Blackstone River begins in Worcester, Massachusetts and flows in a generally southeasterly direction to its mouth at the Main Street Dam in Pawtucket, Rhode Island. Several miles of the river in Blackstone, Massachusetts and Woonsocket, Rhode Island are channelized by Corps local protection projects. Below this dam, the river becomes a tidal estuary known as the Seekonk River. The Seekonk feeds the Providence River seven miles downstream in Providence, Rhode Island, which in turn discharges to Narragansett Bay. A general basin map of the Blackstone River is provided as Figure 1.

The principal tributaries of the Blackstone River are Kettle Brook, Quinsigamond, Mumford, West, Branch, and Mill Rivers. The largest headwater tributary is Kettle Brook, which has its origin about 7 miles northwest of the city of Worcester. Kettle Brook terminates at Curtis Pond where Tatnuck and Beaver Brooks join it to form the Middle River, which in turn is joined by Mill Brook in the southern part of Worcester to form the Blackstone River. The following is a brief discussion of the major tributaries.

<u>Kettle Brook</u>. Kettle Brook has its source near Paxton Center and follows a southeasterly course through Leicester and Auburn to Stoneville, where it turns in a northeasterly direction before entering Leesville Pond. From there it flows northwesterly into Curtis Pond in Worcester and joins Tatnuck and Beaver Brooks to form the Middle River. Kettle Brook falls approximately 650 feet in its 13 mile length and a total drainage area of 34 square miles. The sub-basin has several natural lakes and water supply reservoirs. In addition, the Corps Worcester Diversion Project, completed in 1960, diverts floodflows from 30.5 square miles of the Kettle Brook watershed to the Blackstone River, bypassing a flood prone section of Worcester.

Beaver Brook. Beaver Brook originates near the city of Worcester's northern border. It flows southward for approximately 4.5 miles before joining Kettle Brook to form the Middle River. The 15.6 square mile Beaver Brook watershed is densely populated and has few ponds, lakes or reservoirs. Much of the brook is either channelized or culverted.

Mill Brook. Mill Brook begins in the town of Holden, Massachusetts, then flows southward to its confluence with the Middle River in the southern portion of Worcester, Massachusetts. Throughout most of its 7.5 mile length, the brook is enclosed in an underground conduit. The terrain along Mill Brook's course is very hilly and heavily urbanized.

Middle River. Flowing generally southeasterly for a distance of about 2.5 miles, Middle River passes through a wetland area and two small ponds. It intercepts Mill Brook to form the Blackstone River at the former American Steel and Wire Company Dam northeast of the Quinsigamond Village in Worcester. The total drainage area of the Middle River Basin is 65 square miles.

Quinsigamond River. The Quinsigamond River watershed has an area of 35 square miles, a length of about 12 miles and a maximum width of 4.5 miles. It includes many hills and numerous lakes and ponds. The largest body of water is the 5-mile long Lake Quinsigamond, located in the headwaters of the watershed, with a water surface area of about 1 square mile. This lake and the ponds downstream, coupled with the flat slope of the Quinsigamond River, have a decided effect on the timing and attenuation of peak floodflows at the mouth of the river. From the outlet of Lake Quinsigamond, the river falls approximately 65 feet in its 5-mile length, joining the Blackstone River in Grafton, Massachusetts (Fisherville Pond).

Mumford River. The Mumford River with an area of 58 square miles flows from the outlet of Manchaug Pond in Sutton, Massachusetts and follows a meandering course in a general easterly direction to its confluence with the Blackstone River at Uxbridge, Massachusetts. In this 17-mile course the river falls approximately 450 feet. Several large ponds and lakes in the headwaters provide considerable natural storage, and in addition, many small dams and reservoirs developed by textile and machinery industries reduce and retard flood discharges. The basin is rural in the upper watershed, but heavily industrialized in the lower portions.

West River. The West River watershed, with an area of 35 square miles, is elongated in shape with a length of about 12 miles and a width varying from about 5 miles in the upper portion to about 2 miles in the lower portion. The basin consists of low, rolling wooded hills and broad valleys with scattered lakes and swamp areas. The Corps flood control project, West Hill Dam, was constructed in 1961 on the West River in Uxbridge, Massachusetts, and controls 27.9 square miles of drainage area during flood events. Elevations range from over 600 feet in the headwaters to 200 feet NGVD at the mouth. The river has its origin at Silver Lake, approximately 2 miles southeast of Grafton, Massachusetts. The West River flows southeasterly from its source through Upton, where it is joined by Warren Brook, then gradually turns to a more southerly course to its mouth about one mile south of Uxbridge. The length of the river is approximately 16 miles, during which it falls about 150 feet.

Branch River. The Branch River, the Blackstone's largest tributary has a triangular-shaped watershed of 96 square miles, of which 13 are in Massachusetts and 83 in Rhode Island. The mouth of the river is near the Massachusetts-Rhode Island state line, about 1.5 miles north of the city of Woonsocket. The Branch River is formed by the confluence of the Pascoag and Chepachet Rivers near the town of Mapleville, Rhode Island and flows northeasterly for about 9 miles to its mouth. The Chepachet River drains the southern part of the watershed, whereas the Pascoag River and its principal tributary, the Clear River, drain the northwestern section. Elevations range from 800 feet in the headwaters to 200 feet NGVD at the mouth. In spite of a hilly terrain, there are many lakes, ponds, and reservoirs which provide minor attenuation of floodflows.

Mill River. The Mill River has its source at North Pond in Milford, Massachusetts and flows southerly to its confluence with the Blackstone River at Woonsocket. In its 18-mile length, the Mill River has a fall of about 230 feet, of which 23 feet occur within a one-mile reach in Woonsocket. The watershed has a drainage area of 35 square miles, about 16 miles long and 2 miles wide, comprised of rolling wooded hills and broad valleys with scattered lake and swamp areas which have a large modifying effect on floods. Harris Pond, impounded by a 36-foot high dam and located at the Massachusetts-Rhode Island state line, failed during the August 1955 flood and destroyed all dams on the lower Mill River within the city of Woonsocket. With the exception of Harris Pond Dam, none of these dams have been replaced.

Peters River. Peters River originates in Bellingham, Massachusetts, just north of Silver Lake. It flows southwesterly for approximately 3.5 miles and then crosses the Massachusetts - Rhode Island State line at Woonsocket. About a mile farther downstream, it joins the Blackstone River via a pressure conduit at the lower Woonsocket local protection project.

Abbott Run. Characterized by many swamps and ponds, Abbott Run flows from the towns of Wrentham and Cumberland along the Massachusetts-Rhode Island border. Near its origin, it is impounded in the Diamond Hill Reservoir which supplies water to the city of Pawtucket, Rhode Island. It then flows southward, joining the Blackstone River in the village of Valley Falls, Rhode Island. Abbott Run has a drainage area of 27 square miles.

2.1.2 Ponds, Lakes and Reservoirs

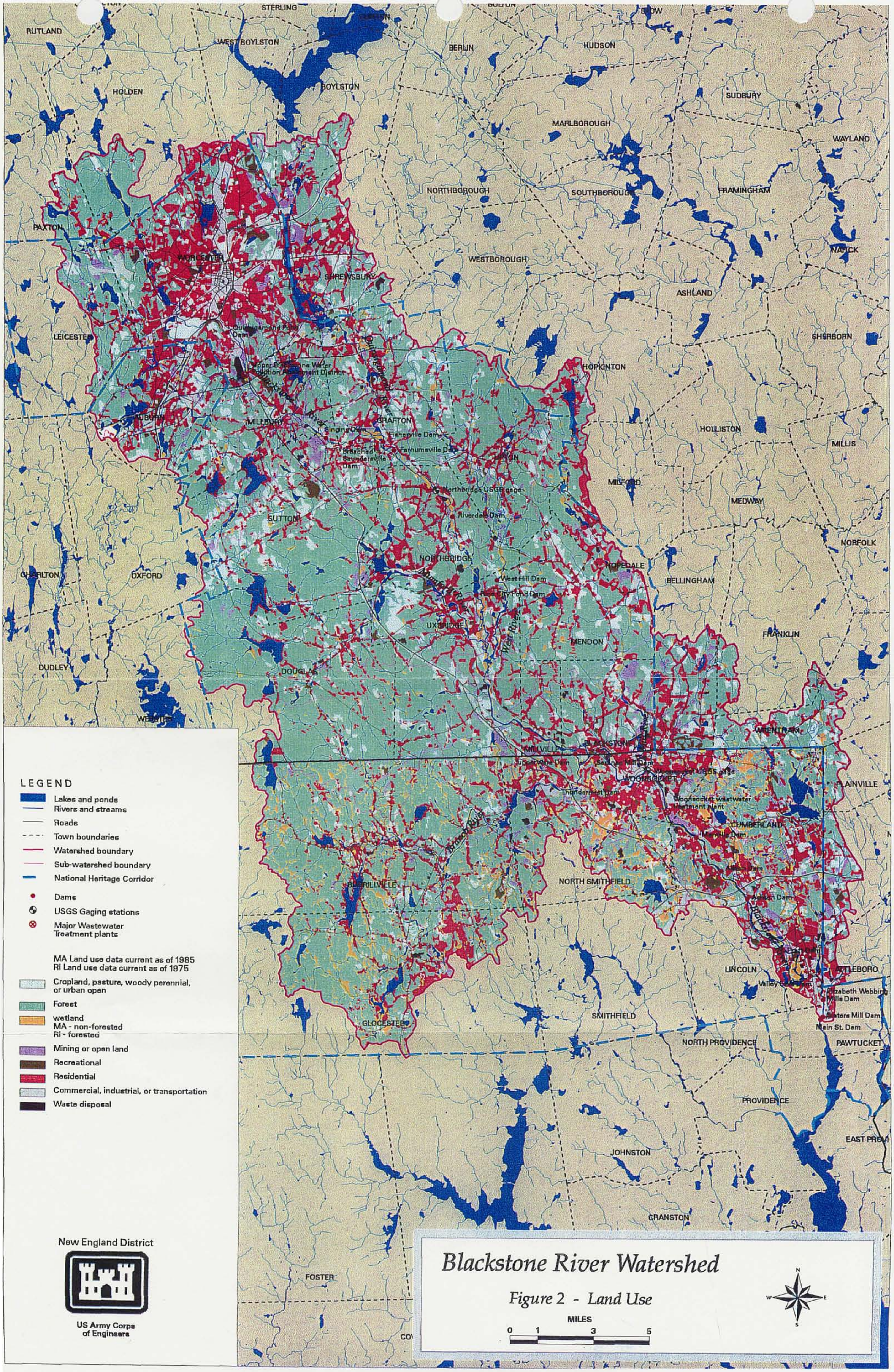
There are about 350 ponds, lakes, and reservoirs the Blackstone River Basin, including about 190 in Massachusetts and 160 in Rhode Island. Most are impoundments created in the 19th or early 20th centuries for hydropower or water supply. Table 1 presents some information on the existing dams on the mainstem river. Tributary dams are not listed due to the major effort required to compile an accurate tabulation.

The largest lake in the Blackstone River basin is Lake Quinsigamond, a 475 acre natural lake on the Quinsigamond River in Worcester, Shrewsbury, and Grafton, Massachusetts. Other large lakes or impoundments include Manchaug Pond in Douglas and Sutton, Massachusetts (348 acres), Singletary Lake in Sutton and Millbury, Massachusetts (330 acres), Wallum Lake in Douglas, Massachusetts (322 acres), and Pascoag Reservoir in Burrillville and Glocester, Rhode Island (349 acres). Several of the large impoundments are water supply reservoirs operated by regional utilities with water quality protected by state and local policies which limit development and other activities within water supply watersheds.

2.1.3 Wetlands

Information about wetlands in the Blackstone River watershed is available from three main sources: the Rhode Island Geographic Information System (RIGIS), the Massachusetts Geographic Information System (MAGIS) databases, and USFWS National Wetland inventory maps. Wetland mapping from the RIGIS and MAGIS databases is shown in yellow on Figure 2. Rhode Island mapping includes both forested and non-forested vegetated wetlands; Massachusetts mapping includes only non-forested vegetated wetland.

A significant percentage of the Blackstone River basin is nonforested wetland. In addition, approximately 40 to 60 percent of wetlands in Massachusetts are forested (as is the case elsewhere in the northeast). A considerable amount of open water wetland habitat and some



STERLING
RUTLAND
WEST BOYLSTON
BERLIN
HUDSON
HOLDEN
BOYLSTON
SUDBURY
MARLBOROUGH
WAYLAND
NORTHBOROUGH
SOUTHBOROUGH
FRAMINGHAM
PAXTON
WESTBOROUGH
NATICK
SHREWSBURY
ASHLAND
LEICESTER
SHERBORN
HOPKINTON
GRAFTON
MILLBURY
HOLLISTON
MILLIS
MILFORD
SUTTON
MEDWAY
NORTHBRIDGE
NORFOLK
CHARLTON
OXFORD
HOPEDALE
BELLINGHAM
UXBRIDGE
FRANKLIN
MENDON
DUDLEY
DOUGLAS
WEBSTER
MILLVILLE
WOONSOCKET
PLAINVILLE
CUMBERLAND
NORTH SMITHFIELD
LINCOLN
ATTLEBORO
SMITHFIELD
GLOCESTER
NORTH PROVIDENCE
PAWTUCKET
PROVIDENCE
EAST PROV
JOHNSTON
CRANSTON
FOSTER
LEGEND
Lakes and ponds
Rivers and streams
Roads
Town boundaries
Watershed boundary
Sub-watershed boundary
National Heritage Corridor
Dams
USGS Gaging stations
Major Wastewater Treatment plants
MA Land use data current as of 1985
RI Land use data current as of 1975
Cropland, pasture, woody perennial, or urban open
Forest
wetland
MA - non-forested
RI - forested
Mining or open land
Recreational
Residential
Commercial, industrial, or transportation
Waste disposal
New England District
US Army Corps of Engineers
Blackstone River Watershed
Figure 2 - Land Use
MILES
0 1 3 5

TABLE 1 - Mainstem Blackstone River Dams (Upstream to Downstream Order)

Dam	Location	Height (ft)	Normal Storage (Ac-ft)	Hazard*
New England Power	Millbury, MA	15	29	Low
Singing	Sutton, MA	10	50	Low
Fisherville Pond	Grafton, MA	10	250	High
Farnumsville[1]	Grafton, MA	10	85	Low
Riverdale[2]	Northbridge, MA	14	88	Low
Rice City Pond	Uxbridge, MA	21	1762	High
Tupperware[2]	Blackstone, MA	12	305	Low
Saranac Mill	Blackstone, MA	17	20	?
Thundermist[2]	Woonsocket, RI	40	300	Signif
Manville	Lincoln, RI	19	58	Signif
Albion	Lincoln, RI	25	495	Signif
Ashton	Lincoln, RI	10	35	Low
Pratt (Lonsdale)	Lincoln, RI	12	?	Signif
Valley Falls[2]	Central Falls, RI	10	80	Signif
Elizabeth Webbing[2]	Pawtucket, RI	10	150	Signif
Slater Mill	Pawtucket, RI	7	?	Signif
Main Street[2]	Pawtucket, RI	7	2.5	Low

1 FERC has recently ruled jurisdiction over the Farnumsville hydropower facility;

2 Denotes FERC licensed facility. Hazard classification is from Phase I inspection reports, FERC licensing applications, and other sources.

emergent habitat has been created in the Blackstone basin through construction of numerous mill dams and water supply reservoirs, though much of this has been offset by wetlands filling and other actions. In many instances, though, construction of these impoundments probably destroyed significant riparian wetland habitat.

A number of large wetland areas are present in the Blackstone River Basin (see Table 2). Most consist of forested wetland and scrub-shrub wetlands systems dominated by red maple. Wetlands with extensive emergent marsh or wet meadow are rare. The most extensive emergent marsh system is the Valley Falls (Lonsdale) Marshes on the Blackstone River in Lincoln and Central Falls, Rhode Island. Diverse emergent marsh/wet meadow systems have also developed on the Blackstone at the Rice City, Fisherville, and Manville Dam impoundments, and at the

Table 2- Large Wetlands Systems in the Blackstone River Basin

Wetland	Location	Size (acres)	Dominant Wetland Community Type (s)
MASSACHUSETTS			
Cedar Swamp	Uxbridge	154	Forested/Open Water
Cider Mill Swamp	Grafton	238	Forested/Scrub-Shrub
Fisherville Pond	Grafton	185	Emergent/Open Water
Hopedale and Mill Ponds	Milford	212	Emergent/Open Water
Lackey Pond Dam	Northbridge, Uxbridge	95	Emergent/Open Water
Mill River	Mendon, Blackstone	168	Forested
Slocum Meadow	Shrewsbury	174	Forested
Rice City Pond	Northbridge, Uxbridge	105	Emergent/Open Water
Riverdale Pond	Riverdale	60	Emergent/Open Water
West River	Upton, Northbridge	150	Forested
RHODE ISLAND			
Cedar Swamp	North Smithfield	NA	Forested
Pratt (Lonsdale) Dam	Lincoln, Cumberland	63	Emergent/Open Water
Valley Falls Marshes	Central Falls, Cumberland	183	Emergent/Open Water

Lackey Dam impoundment on the Mumford River. Most of the numerous large lakes and reservoirs in the basin consist primarily of open water, with little emergent marsh.

2.1.4 Riparian Habitat

Riparian habitat refers to land adjacent to rivers, streams, lakes and impoundments. Riparian habitat is generally defined as including the floodplain or at least 100 to 200 feet outward from the riverbank or shoreline, whichever is greater. No studies have attempted to map riparian habitat or the condition of riparian "buffers" in the Blackstone River watershed. In many places, however, especially along the Blackstone River and the lower reaches of major tributaries, riparian habitat is extensively developed. Along the Blacktone River, riparian buffers are often less than 100 ft. wide, and in many heavily developed areas, less than 25 feet wide. Substantial undeveloped habitat remains in protected areas along the Blackstone River (e.g. Rice City Pond), north of Church Street in Northbridge, south of Mendon Street (Rte. 16) in Uxbridge, and in the upper reaches of some tributary streams.

Remaining riparian habitat in the Blackstone River basin is primarily wooded. Forested riparian areas are typically dominated by red maple. White pine and oak are common in drier locations. Common species in scrub-shrub riparian habitat include alder, dogwoods, willows, and buttonbush.

2.1.5 Upland

Undeveloped upland habitat in the Blackstone River basin is primarily forested. The basin lies in the "Central Hardwoods-Hemlock-White Pine" forest region. This region has a mixture of species common to more northerly or southerly areas. Until it was wiped out by the Chestnut blight late in the 19th century, American chestnut was the dominant tree. Red, black, and white oaks, hickories, gray, yellow, and black birches, and maple are the major species, with red maple occurring in wetter sites. White pine and hemlock are the primary evergreens.

Open land (see Figure 3 - Blackstone River Watershed Open Space) is typically colonized by shrub species such as staghorn sumac, gray birch, and white pine saplings. Although some pasture is present, large patches of grassland habitat that is not grazed or regularly mowed is very rare.

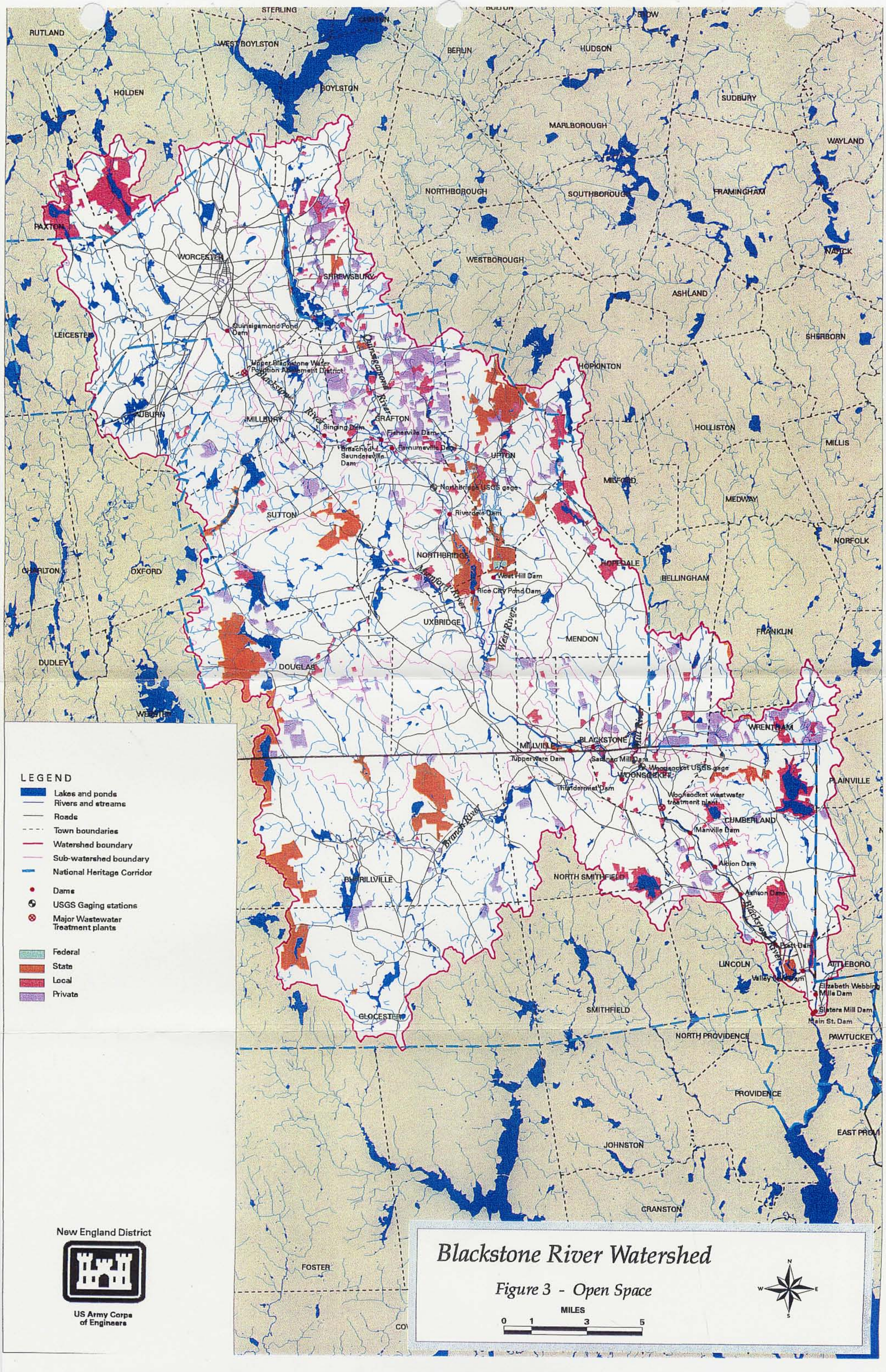
2.1.6 Geology, Soils and Groundwater

2.1.6.1 **Bedrock and Surficial Geology**. The Blackstone River Basin is located within two major physiographic regions, the New England Upland Region and the Narragansett Basin. Topography ranges from the low hills and plains of less than 200 feet above sea level in the Narragansett Basin (located in the southern portion of the Blackstone River Basin) to elevations ranging from 300 to over 1,000 feet above sea level in the New England Region (located in the northern portion of the Blackstone River Basin). Bedrock within the Blackstone River Basin is comprised of igneous, metamorphic, and sedimentary rocks consisting of granite, quartzite, schist, phyllite, gneiss, shale, sandstone, and conglomerate.

The current landforms were modified by erosion and glacial processes. As the glacier retreated it left deposits of glacial outwash material comprised of clay, silt, sand, and gravel which blanket the area today. In addition, glacial till was deposited and consists of unsorted sizes of materials (clay to boulders). The till is widely distributed in the basin and usually occurs as a thin blanket over the bedrock surface and is generally thicker in the valleys. The extensive deposits of till and outwash have created numerous swamps and ponds observed throughout the region. Since the last glacial period, there probably has been slight uplift of the region, some renewed erosion in the larger stream valleys and filling in of ponds with vegetation; but the topography of today remains essentially that of the late post glacial time of at least 12,000 years ago.

2.1.6.2 **Soils**. The soil profile in the Blackstone Valley is typically fine deposits (flood plains only) underlain by glacial outwash or till, and bedrock. The fine deposits are loose mixtures of clay, silt and sand that may or may not be sorted. Exploration logs indicate that they are typically less than 10 feet thick. The outwash and till are dense heterogeneous mixtures of clay, silt, sand, gravel, cobbles and boulders. The outwash tends to have a smaller gravel, cobble and boulder content than the till. In most cases, the till is 10 to 20 feet in thickness and mantles the bedrock in the upland areas. It is also commonly found in valley areas at the base of the stratified drift aquifer discussed below. Sediments in the basin have been deposited by erosional processes in backwater areas and behind obstructional features such as the existing dams. Much of the sediment may be contaminated due to past industrial activities that occurred along the river.

2.1.6.3 **Groundwater**. Till 10 to 20 feet thick often covers the bedrock in the upland areas. Water is stored in porous voids in the till layer and in open fractures in the upper few hundred feet of bedrock. Well yield is typically between 2 and 15 gallons per minute. Both


Blackstone River Watershed
Figure 3 - Open Space
MILES
0 1 3 5
N
S
E
W
LEGEND
Lakes and ponds
Rivers and streams
Roads
Town boundaries
Watershed boundary
Sub-watershed boundary
National Heritage Corridor
Dams
USGS Gaging stations
Major Wastewater Treatment plants
Federal
State
Local
Private
New England District
US Army Corps of Engineers
STERLING
RUTLAND
WEST BOYLSTON
CLINTON
BERLIN
HUDSON
STOW
HOLDEN
BOYLSTON
SUDBURY
MARLBOROUGH
WAYLAND
NORTHBOROUGH
SOUTHBOROUGH
FRAMINGHAM
PAXTON
WORCESTER
WESTBOROUGH
NATICK
SHREWSBURY
ASHLAND
LEICESTER
Quinsigamond Pond Dam
Quinsigamond River
SHERBORN
HOPKINTON
Upper Blackstone Water Pollution Abatement District
AUBURN
MILLBURY
Singing Dam
GRAFTON
Fisherville Dam
Farnumsville Dam
Breached Saundersville Dam
UPTON
HOLLISTON
MILLIS
Northbridge USGS gage
MILFORD
MEDWAY
SUTTON
Riverdale Dam
NORFOLK
CHARLTON
OXFORD
NORTHBRIDGE
HOPEDALE
West Hill Dam
BELLINGHAM
Mumford River
Rice City Pond Dam
UXBRIDGE
West River
MENDON
FRANKLIN
DUDLEY
DOUGLAS
WEBSTER
Mill River
MILLVILLE
BLACKSTONE
WRENTHAM
Tupperware Dam
Saranac Mill Dam
Woonsocket USGS gage
WOONSOCKET
PLAINVILLE
Thundermist Dam
Woonsocket wastewater treatment plant
Branch River
CUMBERLAND
Manville Dam
Albion Dam
BURRILLVILLE
NORTH SMITHFIELD
Ashton Dam
Blackstone River
Pratt Dam
LINCOLN
ATTLEBORO
Valley Falls Dam
Elizabeth Webbing Mills Dam
Sisters Mill Dam
Main St. Dam
GLOCESTER
SMITHFIELD
NORTH PROVIDENCE
PAWTUCKET
PROVIDENCE
EAST PROV
JOHNSTON
CRANSTON
FOSTER

groundwater and surface water sources are utilized by Rhode Island and groundwater is the primary source outside of the Worcester area in the Massachusetts portion of the basin.

Throughout most of the Blackstone River Basin, the stratified drift aquifer averages 40 feet in thickness or more and averages 500 feet or less in width. Stratified drift consists of sorted and layered materials deposited by a meltwater stream or settled from suspension in a body of quiet water adjoining a glacier. The thickest and most transmissive part of the aquifer is beneath the river. Yields of 200 gallons per minute and greater are obtainable from many wells placed in close proximity to the river. The yield of the stratified drift aquifer is dependent in part upon the rate at which infiltration can be induced from the river.

Man-made impacts on groundwater have occurred. Impacts to the groundwater have resulted due to residential waste systems, fertilizers/pesticides from residential and agricultural application, runoff of deicing salts from highways, landfill leachate, and infiltration from the degraded streams of the basin. This has resulted in an increase in water hardness as well as chlorides, sulfates, and nitrates. The quality of groundwater in the Blackstone River Basin is generally good with the exception of the presence of high concentrations of manganese and iron and low pH.

2.1.7 Social and Economic Setting (Population and Employment)

The cities and towns along the Blackstone River include a range of communities from large cities to small towns. The City of Worcester, at the river's head, is the second largest city in Massachusetts, second only to Boston. The City of Pawtucket, where the river ends and becomes the Seekonk River, is the fourth largest city in Rhode Island in terms of population, after Providence, Warwick, and Cranston. In general, the communities along the river in Massachusetts, with the exception of Worcester, are typically small towns. Conversely, in Rhode Island, the communities along the river are generally larger towns or small cities. Table 3 shows the 1990 population of the cities and towns along the river, based on the 1990 US Census, the last census update/survey date.

Table 3 - 1990 Population
Cities and Towns along the Blackstone River

Municipality	1990 Population
MASSACHUSETTS	
Worcester, city	169,759
Millbury	12,228
Sutton	6,824
Grafton	13,035
Northbridge	13,371
Uxbridge	10,415
Millville	2,236
Blackstone	8,023
RHODE ISLAND	
Woonsocket, city	43,877
North Smithfield	10,497
Cumberland	29,038
Lincoln	18,045
Central Falls, city	17,637
Pawtucket, city	72,644

The nature of the economies and employment in the different cities and towns along the Blackstone River varies. Worcester is a very large city and has a major employment base. Many of the small towns around Worcester, including those along the river to the southeast, serve as suburbs of Worcester, and, to a lesser extent, distant suburbs of Boston. As a large city, Worcester is urban in nature, with high population density, high levels of development, and a large and diverse number of employers, including manufacturing businesses, colleges and universities, and numerous retail and wholesale trade businesses. In contrast, the towns along the river in Massachusetts to the south and east of Worcester are much less developed, with areas of suburban development, large areas of open space, and significantly fewer employers.

In Rhode Island, the cities of Woonsocket, Central Falls, and Pawtucket are small to medium-sized cities, with areas of both urban and suburban development, and with a significant number and variety of employers. The towns of North Smithfield, Cumberland, and Lincoln are generally suburban in nature.

Current employment data for the communities along the Blackstone River are shown in Table 4, below. All data shown reflect September 1996 employment information.

Table 4 - Employment, September 1996
Cities and Towns along the Blackstone River

Municipality	Labor Force	Unemployment Rate
MASSACHUSETTS, State	3,157,000	5.3%
Worcester, City	75,974	4.4
Millbury	6,628	4.3
Sutton	3,991	3.3
Grafton	7,121	3.4
Northbridge	6,592	5.2
Uxbridge	5,878	3.4
Millville	1,390	5.5
Blackstone	4,467	5.3
RHODE ISLAND, State	494,400	5.1
Woonsocket, City	19,127	7.1
North Smithfield	5,204	3.0
Cumberland	16,069	4.3
Lincoln	9,960	5.0
Central Falls	6,671	8.0
Pawtucket, City	35,389	6.1

2.1.8 Land Use

Land use in the cities and towns along the Blackstone River ranges from highly developed and urbanized to undeveloped open space (see Figure 2 - Blackstone River Watershed Land Use). About 70 % of the basin is undeveloped and mostly forested (see Table 5). The remaining 30 % of the basin is developed primarily for residential purposes.

Cities such as Worcester, Massachusetts and Woonsocket, Cumberland, Lincoln, Central Falls and Pawtucket, Rhode Island are primarily urban in nature, containing a high level of development. Many of the towns along the river are more suburban in nature. Many of the communities along the mainstem river have relatively sparse residential development and areas of

Table 5 - Land Use

Category	Percentage Rhode Island	Massachusetts
Undeveloped		
Forest	52.7	57.4
Wetland	14.2	1.7
Surface Waters	?	3.2
Open Land	1.5	2.4
Developed		
Residential	19.2	19.6
Commercial	2.7	1.4
Industrial	1.4	1.3
Urban	-	1.9
Cropland and Pasture	3.7	7.0
Transportation	1.0	1.5
Mining	1.7	0.9
Recreation	0.9	1.1
Waste Disposal	0.8	0.3
Other	0.3	0.3

open space. Many have the small town centers or villages characteristic of the mill/village setups of the early industrial age.

Significant portions of the land immediately along the banks of the mainstem of the Blackstone River in Massachusetts are owned by the New England Power Company, and numerous other portions of land along the river in Massachusetts contain cemeteries and municipal wastewater treatment plants. In general, the land immediately along the banks of the river in Rhode Island is more often public parks or urbanized development, compared to Massachusetts.

2.1.9 Climate

The Blackstone River basin has a variable, temperate climate with frequent weather changes, although a prolonged drought may occur lasting a month to a year or more. The basin usually experiences moderate local showers or thunderstorms during the summer, but in the fall, winter, and spring months, storms of extra-tropical origin produce longer periods of precipitation. However, some of these storms can intensify over the ocean and produce coastal storms with strong winds and heavy rain (or snow) that are known locally as "Northeasters." During the late summer or early fall, tropical storms or hurricanes have passed up the Atlantic coastline near enough to produce significant amounts of rainfall accompanied by damaging winds. These types of events can produce severe river and stream flooding throughout the entire basin.

The average annual temperature of the basin is about 49 degrees Fahrenheit. Average monthly temperatures vary widely throughout the year, from between 25 degrees Fahrenheit in January to 73 degrees Fahrenheit in August. Extremes in temperature range from occasional highs slightly in excess of 100 degrees Fahrenheit to infrequent lows in the minus twenties, particularly in the northern portions.

The mean annual precipitation is about 41 inches, generally distributed uniformly throughout the year. The annual range between maximum and minimum values of mean monthly precipitation does not exceed one inch. Monthly precipitation extremes at a gage in nearby Providence, Rhode Island range from a minimum of 0.07 inch in March to a maximum of 12.24 inches in August 1955, and at Worcester 0.04 inch in March to 18.58 inches in August 1955. The maximum 24-hour precipitation recorded at Worcester and Providence was 8.67 and 6.67 inches, respectively, during the 18-19 August 1955 storm.

About one-third of the precipitation during the winter months is in the form of snow. Annual snowfall averages from 35 to 40 inches, with extremes ranging from less than one foot in the southern portions of the basin to over 100 inches at northern inland points. Average water content of the snow cover rarely exceeds 3 inches, however, maximum water contents of over 7 inches have been experienced in the Blackstone River Basin.

2.1.10 Hydrology

The following sections summarize information provided in Appendix H.

2.1.10.1 Mainstem Blackstone River. There is limited gaged streamflow information available on the Blackstone River. The USGS operates and maintains river gaging stations on the mainstem river only at Northbridge, Massachusetts and at Woonsocket, Rhode

Island. Flows recorded at these two gaging stations were considered representative of flows for much of the length of the river. The USGS gaging station at Northbridge (141 square mile drainage area) was operated continuously from 1940 to 1977. In addition, peak annual discharges are available for 1936 and 1979, and the USGS began collecting streamflow records again in 1996. The USGS gaging station at Woonsocket (416 square mile drainage area) has been operated continuously from 1929 to present.

Flow regimes on the Blackstone River below Northbridge are influenced by the Corps flood control project, West Hill Dam, which controls 27.9 square miles (15 percent) of the Blackstone River's watershed during flood events or during periods with high flood potential. During non-flood events, the project has little or no impact on flows since it passes the inflow. Other dams on the river provide negligible flood control storage with the incidental flood control benefits coming from the natural attenuation of peak flows due to limited spillway and outlet capacity and use of the minor surcharge storage available. Low flows are impacted by wastewater treatment plants and other operations. Relatively short-term and non-natural flow fluctuations are believed to be caused by one or more of the hydropower facilities located on the mainstem river. The lack of gages on the mainstem river make it difficult to ascertain the facility(s) causing the fluctuations. The general urbanization of the basin is also likely to be impacting flow regimes by reducing base flows and making the stream "flashier".

Monthly Flows. Monthly flows on the Blackstone for the period of record at the two gage locations and maximum and minimum daily flows are shown in Table 6. Average annual flows at Northbridge and Woonsocket are 267 and 774 cubic feet per second (cfs). This equates to 1.89 and 1.86 cubic feet per second per square mile, respectively. The average flows include the average return flow from the Upper Blackstone Water Pollution Abatement District (UBWPAD) of 60.7 cfs (varies from a low of 45 cfs in July and September to a high of about 77 cfs in May), of which about 14 cfs is an interbasin transfer from the Nashua River basin for water supply. UBWPAD is by far the most significant discharger to the Blackstone River.

Based on a Corps regional analysis of other gaged waterways which flow into Narragansett Bay, average annual flow from the Blackstone is considered to be average for that area. Mean annual flows into the bay ranged from 1.7 to 2.1 csm. As stated above, average annual flow in the Blackstone River at Woonsocket is about 1.86 csm.

TABLE 6 - Discharges on the Blackstone River (cfs)

	Northbridge, Massachusetts 141 square miles 1940-1979			Woonsocket, Rhode Island 416 square miles 1929-1995		
Month	**Mean Monthly**	**Maximum Daily**	**Minimum Daily**	**Mean Monthly**	**Maximum Daily**	**Minimum Daily**
January	282.0	2,120	14	950.9	12,500	109
February	324.5	2,930	22	987.5	7,140	109
March	514.8	3,910	74	1,507.0	14,200	187
April	475.1	2,280	101	1,424.0	8,960	302
May	302.5	1,780	60	879.6	5,770	139
June	225.2	1,590	8.7	605.3	10,900	44
July	141.9	2,220	4.7	330.0	13,700	29
August	144.7	8,850	2	316.9	25,900	21
September	145.6	3,680	2	330.4	8,530	29
October	156.7	2,640	8	419.4	8,310	36
November	224.3	1,990	5	668.5	5,640	36
December	263.3	1,590	8.7	866.3	5,300	79
Annual	266.7	2,965	25.8	773.8	10,570	93.3

Low Flows. Low flow analyses were not performed for this Reconnaissance Study, however, in 1984 the USGS published low flow data in the "Gazetteer of Hydrologic Characteristics of Streams in Massachusetts - Blackstone River Basin." $_7Q_2$ (7-day, 2-year low flow, i.e. the minimum average flow rate that is predicted to occur for 7 consecutive days at an average of one time per 2 years) is 72 cfs and 134 cfs for the Northbridge gage and Woonsocket gage, respectively, and $_7Q_{10}$ (7-day, 10-year low flow) is 45 cfs and 101 cfs for the Northbridge gage and Woonsocket gage, respectively. During low flow periods, return flow from the Upper Blackstone Water Pollution Abatement District plant accounts for most of the flow in the Blackstone River above Northbridge. According to published USGS reports, the effects of storage releases on low flows was probably significantly greater prior to 1952, when most of the mill dams were still operating on the Blackstone.

Flood Flows. Moderately high springtime discharges frequently occur as the result of melting snow, but runoff from this source alone has been insufficient to cause any major floods during the period of record. However, serious flooding from a combination of melting snow and heavy rain is an annual possibility.

Flood flows were analyzed at the two mainstem USGS river gaging station locations on the Blackstone River. Peak annual flows at Northbridge and Woonsocket were ranked and fitted with a log Pearson Type III distribution. The 10-, 50-, 100-, and 500-year discharges calculated by the Corps for the Northbridge gage are 4,300, 7,950, 10,200, and 17,300 cfs, respectively. These values are essencially the same as those published in the Federal Emergency Management Agency's (FEMA) 1982 Flood Insurance Study (FIS) for Northbridge. Peak annual flows at Woonsocket were analyzed by the Corps for the period from 1961 to present. Peak flows for the floods of 1936, 1938, and 1955, as modified by West Hill Dam, were determined and included in the analysis. The USGS reports that the flood of August 1955 is the largest flood experienced on the Blackstone in Woonsocket since 1645, however, this analysis considers it the flood of record since 1936. The 10-, 50-, 100-, and 500-year flows were computed to be 13,100, 21,000, 25,000, and 36,000 cfs, respectively. Differences between these values and FEMA's values published in the 1981 FIS for Woonsocket are believed due to the longer period of record, an additional 16 years, included in this analysis.

2.1.10.2 Tributaries. The USGS has operated a streamflow gaging station on the Quinsigamond River at North Grafton, Massachusetts since 1939. Average daily flow for this

25.6 square mile drainage area is about 41 cfs. The highest recorded peak discharge was 820 cfs in August 1955; lowest recorded flow was zero in August 1966.

The USGS operated a streamflow gaging station on the Mumford River from 1939 to 1951 at East Douglas, Massachusetts. For this period of record, average daily discharge is about 45 cfs for this 27.8 square mile drainage area. The highest peak discharge recorded at this gage was 420 cfs in March 1948; lowest recorded flow was 2 cfs in both February and August 1944.

The USGS operated a streamflow gaging station on the West River in Uxbridge, Massachusetts, just below West Hill Dam (27.9 square mile drainage area). Average daily discharge for the period 1962 to 1990 was about 49 cfs (adjusted for storage). Maximum peak discharge, affected by flood control regulation, was 607 cfs in June 1984; lowest discharge was zero flow during August 1967.

The USGS has operated a streamflow gaging station on the Branch River at Forestdale, Rhode Island since 1940. The site has a drainage area of 91.2 square miles. Average daily discharge for the period of record is 175 cfs. Maximum recorded instantaneous flow was 5,470 cfs in January 1979; lowest recorded flow was 5 cfs in October 1948.

From the period 1923 to 1978, the USGS operated a streamflow gaging station at Worcester on Kettle Brook. Average daily flow for this period is about 53 cfs. The record for this 31.3 square mile drainage area has been adjusted for estimated diversions through the Worcester Diversion Project. Extremes for the period of record include a peak flow of 3,970 cfs in August 1955 and a low flow of 0.2 cfs in May 1940.

2.1.11 Water Quality

The following sections summarize information provided in Appendix G.

2.1.11.1 <u>Mainstem Blackstone River.</u> In general, current water quality problems in the Blackstone River are typical of older, highly urbanized river basins. Problems include suspended solids, fecal coliform, algal growth problems associated with excessive nutrients, significant variations in pH, dissolved oxygen (DO), turbidity, and heavy metals. The contaminants, originating from point and nonpoint sources, stress the stream's natural capacity to assimilate waste. Another large problem is water quality degradation from historical accumulation of polluted sediments.

Numerous surveys and studies have been conducted within the last several years by the Narragansett Bay Project, MADEP, EPA, RIDEM, URI, and others to determine water quality conditions within the Blackstone River Basin. All studies prior to the comprehensive Blackstone River Initiative (BRI) effort in 1991, collected for various State agencies, provide only a snapshot of water quality conditions in the river at the time of sampling.

The BRI was organized in recognition of the primary importance of the Blackstone River to the future of Narrragansett Bay. The BRI was established to conduct the sampling, assessment, and modeling work necessary for restoration of the river system and to prevent further deterioration of the resources of Narragansett Bay. It provided a multi-phased basin-wide assessment of the river, tributaries, and discharges under both low flow and storm conditions.

Based on available BRI sampling information, the Blackstone River basin was divided into nine reaches for analysis. Reach 1 extends from Blackstone River headwaters to Millbury Street in Worcester, reach 2 from Millbury Street to Singing Dam, reach 3 from Singing Dam to Fisherville Dam, reach 4 from Fisherville Dam to Rice City Pond Dam, reach 5 from Rice City Pond Dam to Route 122, reach 6 from Route 122 to Massachusetts/Rhode Island State line, reach 7 from the State line to Woonsocket WWTF, reach 8 from Woonsocket WWTF to Pratt Dam, and reach 9 from Pratt Dam to Slaters Mill. Table 7 presents water quality classification, status, water quality problems, and possible sources of these problems for each reach.

a. Reach 1. This section of the Blackstone River, extending from the headwaters to Millbury Street in Worcester, is non-supporting of Massachusetts Class B uses. General problems are low dissolved oxygen, high ammonia-nitrogen, nitrate-nitrogen, and fecal coliforms, and violations of metal toxicity criteria. Under low flow conditions, most constituent loadings in the headwaters are small compared to point sources in downstream reaches. Exceptions to this are fecal coliforms, ammonia-nitrogen, copper, and lead, which are high in concentration under all conditions. BOD_5 and total suspended solids concentrations were the highest of the entire river during wet weather flows, showing the significance of urban runoff and the Worcester combined sewer overflow (CSO). There is a significant source of lead and ammonia-nitrogen in this reach. Overall, this reach is a major source of total suspended solids (TSS), BOD, fecal coliforms, lead, and ammonia. These are attributed to both point and nonpoint sources.

b. Reach 2. This 5.9-mile stretch of river, starting at Millbury Street and continuing downstream to Singing Dam, includes the UBWPAD, New England Power Company Dam, Millbury Wastewater Treatment Plant (WWTP), and Singing Dam impoundment. Water quality is generally degraded with high BOD_5, total suspended solids, fecal coliforms, and nutrients and several violations of metal criteria. This reach generally has the highest cadmium, nickel, lead, copper, phosphate, and nitrate-nitrogen concentrations on the main stem Blackstone River and is nonsupporting of Massachusetts Class B uses. Several sampling efforts have shown that, under high and low flow conditions, the UBWPAD is a major source of metals and nutrients to the Blackstone River. Its discharge affects the concentrations of these parameters downstream to Rice City Pond (reaches 3 and 4). The UBWPAD is also a source of TSS, BOD, and fecal coliforms in this reach. Nonpoint source increases of TSS, fecal coliform, BOD, nutrients, and metals were also observed. Sediments in the Singing Dam impoundment were some of the most polluted of those sampled.

c. Reach 3. This 3.5-mile section of river, beginning below Singing Dam and ending at Fisherville Dam, contains the breached Saundersville Dam, the confluence with the Quinsigamond River, and Fisherville Dam impoundment. Under low flow conditions, this reach has high nutrient concentrations and some metal criteria violations. Metal concentrations, though still high, decreased slightly through the reach. This could have been due to settling in the impoundments or uptake of biomass. Under high flows, there were no significant increases in any parameter. There were, however, slight increases in TSS which were attributed to sediment resuspension. The entire reach was nonsupporting of Class B designated uses. Sediments in Fisherville Pond were found to be highly contaminated with metals.

d. Reach 4. Included in this 8.5-mile reach, which starts below Fisherville Dam and continues downstream to Rice City Pond Dam, are Farnumsville Dam, Grafton WWTP, Northbridge WWTF, the former Rockdale Pond (Coz Chemical), Riverdale Dam, and Rice City Pond. Water quality is degraded in this reach by high BOD_5, suspended solids, fecal coliform, nutrients, and metal concentrations. Metal concentrations around Rice City Pond were some of the highest measured on the entire mainstem river. Concentrations of many constituents including TSS, ammonia-nitrogen, orthophosphate, and metals increased around Rice City Pond, indicating that sediment resuspension is a major source of contamination. This reach is nonsupporting of its designated Class B uses. Sediment quality in this reach was the most polluted of those sampled with extremely elevated metal concentrations in Rice City Pond.

e. Reach 5. This 4.6-mile section of river, which begins below Rice City Pond Dam and continues downstream to Route 122, includes the confluences of the West and Mumford Rivers. This reach generally has high fecal coliform and total suspended solids concentrations. Nutrient and metal concentrations, though still high, decrease from upstream to downstream indicating that no significant point or nonpoint source exist in this reach. Metal concentrations on the Mumford and West Rivers were lower than main stem concentrations and did not seem to be a major source of metals contamination. This reach is partially supporting of Massachusetts Class B uses. Causes of impairment include low pH, nutrients, and metals.

f. Reach 6. Most of this 6.6-mile section of the Blackstone River, which begins below Route 122 and ends at the State line, support but threaten Massachusetts Class B designated uses. Most pollutant concentrations in this reach are level or declining but still generally above recommended criteria. Concentrations of metals decrease gradually through this reach with no apparent point or nonpoint sources.

g. Reach 7. The Mill and Peters Rivers merge into the Blackstone in this 3.8-mile reach, which begins at the State line and ends above the Woonsocket WWTF. This reach generally has slightly elevated BOD_5 and nutrient concentrations and metal criteria violations. Nutrient and metal concentrations generally stayed the same or decreased slightly indicating no significant point or nonpoint sources exist in the reach. The entire section is non-supporting of its Rhode Island Class C designation due to high metals.

h. Reach 8. This 9.6-mile section of river begins just above the Woonsocket WWTF and continues downstream to Pratt Dam. Along with the Woonsocket WWTF, it includes Manville, Albion, and Ashton Dams. The reach has high BOD_5, fecal coliform, nutrient, and metal concentrations. Water quality conditions in this reach appear to be slightly degraded by both pollutants discharging from the Woonsocket WWTF and nonpoint sources. The Woonsocket WWTF is a major source of ammonia-nitrogen, TSS, and fecal coliforms to the river. Nonpoint sources contribute additional TSS, ammonia-nitrogen, nitrate-nitrogen, and orthophosphate. It is nonsupporting of Rhode Island Class C uses due to high metals.

i. Reach 9. This 2.9-mile section of river, which begins below Pratt Dam and concludes at Slaters Mill, includes the Valley Falls, Elizabeth Webbing, and Slaters Mill Dams, just upstream of the end of the mainstem Blackstone River. This reach is degraded by high BOD_5, nutrients, and metals. Nonpoint sources in this reach contribute fecal coliforms and nutrients to the river. It is nonsupporting of Rhode Island Class C uses due to high metals.

TABLE 7
WATER QUALITY CLASSIFICATION, STATUS, PROBLEMS AND SOURCES

REACH	CLASS	STATUS	PROBLEMS	POSSIBLE SOURCES IN REACH
1	MA B	NS	Fecal Coliforms Low DO Ammonia-nitrogen Lead and Copper	Urban runoff Storm sewers Worcester CSO
2	MA B	NS	BOD Suspended solids Fecal coliforms Nutrients Metals	UBWPAD Storm sewers Urban runoff
3	MA B	NS	Nutrients Metals	Resuspension of sediment
4	MA B	NS	BOD Fecal coliforms Nutrients Metals	Resuspension of sediments Overland runoff Storm sewers
5	MA B	PS	Fecal coliforms Nutrients Metals Low pH	Overland runoff
6	MA B	PS	Fecal coliforms Nutrients Metals	
7	RI C	NS	Nutrients Metals	
8	RI C	NS	Nutrients Metals Fecal coliforms	Woonsocket WWTF Overland runoff Storm sewers
9	RI C	NS	Nutrients Metals Fecal coliforms	Overland runoff Storm sewers

NS = non-supporting PS = partially-supporting

2.1.11.2 Tributaries. Based on available BRI sampling information, six tributaries of the Blackstone River basin are examined.

Quinsigamond River. From the 1977 and 1991 surveys, the biggest concerns of the Quinsigamond River appear to be elevated nutrients, fecal coliforms, copper, and lead. Suspended solids and BOD_5 do not appear to be a concern on the Quinsigamond. According to the Massachusetts OWM, the Quinsigamond supports but threatens Class B uses due to pH, nutrients, and toxicity.

West River. Studies indicate that, overall, the West River has low dissolved oxygen, and high ammonia-nitrogen, nitrate-nitrogen, copper, zinc, and lead concentrations. Metal concentrations were generally lower than those on the mainstem Blackstone and did not seem to be a major source of metal contamination.

Mumford River. Generally, the water quality of the Mumford River is degraded by low dissolved oxygen and high BOD_5, fecal coliforms, nutrients, copper, and lead. Metal concentrations were generally lower than those on the mainstem Blackstone and did not seem to be a major source of metal contamination.

Branch River. Limited sampling data available on the Branch River indicates high ammonia-nitrogen, nitrate-nitrogen, fecal coliforms, copper, and lead.

Mill River. Overall, the Mill River has elevated ammonia-nitrogen, nitrate-nitrogen, copper, and lead concentrations.

Peters River. Limited sampling indicates that the Peters River is degraded by low dissolved oxygen and high BOD_5, fecal coliforms, ammonia-nitrogen, nitrate-nitrogen, cadmium, copper, and lead.

2.1.11.3 Point Versus Nonpoint Discharges. One objective of the BRI was to evaluate point and nonpoint sources of contaminants in the Blackstone River watershed. The report had several conclusions based on dry and wet weather monitoring. Ammonia-nitrogen and orthophosphate were clearly governed by point sources. Lead had the highest nonpoint percentage, with highest loadings from Worcester headwaters and Rice City Pond.

TSS, BOD_5, and Fecal Coliforms. Looking at both point and nonpoint sources, McCracken Road to Singing Pond Dam, the headwaters, and Woonsocket are the major contributors of total suspended solids (TSS) and UBWPAD, headwaters, and Millbury Street to McCracken Road are the major contributors of BOD_5. The headwaters, UBWPAD, and Ashton Dam to Slaters Mill Dam supply the most fecal coliforms to the Blackstone River. Eliminating point sources, the headwaters to Singing Dam is identified as contributing over 50 percent of TSS. Other important reaches are Route 122 to Woonsocket WWTF, Rice City Pond, and immediately downstream of Rice City Pond. The majority of nonpoint sources of BOD_5 and fecal coliforms are in the reach from the headwaters to Singing Dam. Other sources are located between Ashton and Slaters Mill Dams and Route 122 to Woonsocket WWTF.

Nutrients. The UBWPAD is the most important source for nutrients (ammonia-nitrogen, nitrate-nitrogen, and orthophosphate) for wet and total loads and delivers almost one-third of the total loads for ammonia-nitrogen. The second most important source of ammonia-nitrogen and orthophosphate is the Woonsocket WWTF. Important nonpoint sources of ammonia-nitrogen were identified in the headwaters, between McCracken Road and Singing Dam, between Fisherville and Riverdale, and between Ashton and Slaters Mill Dams. Major nonpoint source gains of nitrate-nitrogen were observed between Route 122 and Saranac Mill Dam and between Manville and Slaters Mill Dams. Also contributing nonpoint sources, although not as significant, were McCracken Road to Fisherville Dam and Saranac Mill Dam to Woonsocket WWTF. Major increases of orthophosphate were measured around Rice City Pond and between Woonsocket WWTF and Pratt Dam. Less significant increases were observed between McCracken Road and Singing Dam, between Fisherville and Riverdale Dams, and in the headwaters.

Metals. The headwaters and resuspension from Rice City Pond are the most important sources of lead. The UBWPAD and Woonsocket are not important sources of lead. Lead also originates from Millbury Street to McCracken Road, from Route 122 to Woonsocket WWTF, and from Ashton Dam to Slaters Mill Dam. UBWPAD is the major source of the other five metals analyzed in this study. Woonsocket WWTF is an important source of copper and zinc, but not nickel, cadmium, or chromium. Rice City Pond and the headwaters are also significant sources for all trace metals. Other reaches of significance include McCracken Road to Singing Dam for copper and cadmium and Millbury Street to McCracken Road for cadmium and chromium. In general, the headwaters, Rice City Pond, and Millbury Street to Singing Dam are the most important reaches for nonpoint source metal contribution.

2.1.11.4 <u>Impacts of Blackstone River on Narragansett Bay.</u> The National Estuary Program was developed in 1984 because of concern for the health and ecological integrity of the nation's estuaries and estuarine resources. Narragansett Bay was selected for the program in 1985 and was designated an "estuary of national significance" in 1988. The Narragansett Bay Project (NBP), formed in 1985, established seven priority issues for the bay; fisheries, nutrients and potential for eutrophication, toxic contaminants, living resources, contaminated seafood, water quality, and recreational uses. Several studies, performed for the NBP and others, were conducted to evaluate the significance of the Blackstone River on Narragansett Bay.

In 1988 and 1989, NBP directed a wet weather study in which five tributaries of the Providence River and upper Narragansett Bay were sampled during three storm events. These tributaries included the Blackstone, Moshassuck, Pawtucket, Ten Mile, and Woonasquatucket Rivers. The study concluded that the Blackstone River is ranked first for seven of fourteen constituents. These include total suspended solids, four metals, and two nutrients. Because of its pollutant contribution to Narragansett Bay, NBP identified the Blackstone River as one of two "Areas of Special Concern" (the other being Mount Hope Bay). A similar ranking for these tributaries was developed as part of the Blackstone River Initiative. The Blackstone River ranked first for all constituents except ammonia, where it was second.

2.1.12 Sediment

2.1.12.1 <u>Sediment Quality.</u> Decades of uncontrolled industrial discharges, along with non-point sources, have resulted in the contamination of sediments in the Blackstone River basin with heavy metals, petroleum hydrocarbons, PCBs, polynucleur aromatic hydrocarbons (PAHs), and pesticides. Contaminant levels are believed to be highest in the impoundments where suspended sediments are most likely to have settled due to slow velocities. It is possible that sediment quality is improving with time as somewhat cleaner sediments settle and cap deeper more-contaminated sediments. Limited coring analyses at a few sites appear to confirm this hypothesis.

A number of studies have analyzed sediment quality in Blackstone River basin impoundments (see Appendix F for a summary of the available data). Data is sparse compared to that collected for water quality purposes. Most of the available data is for Blackstone River impoundments in Massachusetts. In general, sediments in mainstem impoundments contain high levels of copper, zinc, lead, chromium, other metals, and PAHs. Singing Pond, Fisherville Pond, Rice City Pond, and the former Rockdale Impoundment are among the most heavily contaminated sites. Some sites, notably Rice City Pond and the former Rockdale impoundment, are also contaminated with PCBs and petroleum hydrocarbons.

Determining the ecological significance of sediment contamination is a difficult task. The effect of a contaminant on aquatic life depends upon several factors. These include the availability of the contaminant, the toxicity of the contaminant to organisms (receptors) present, the persistence of the contaminant in the environment, and synergistic effects with other contaminants.

Unlike water quality, there are few criteria available for sediment quality. The Ontario Ministry for the Environment developed guidelines for screening freshwater sediment. The concentration of metals in Blackstone River impoundments are generally much greater than the Ontario criteria, suggesting that a significant risk to most benthic species may exist. This conclusion is supported by toxicity testing conducted by the Blackstone River Initiative which found that pore (soil) water from many impoundments is toxic.

Another measure of sediment quality in impoundments, although indirect, is the condition of the benthic invertebrate communities. Limited data available for Fisherville Pond (see Appendix I) suggests that the benthic invertebrate community is moderately degraded. Additional studies are obviously needed to establish the relationship(s) of sediment chemistry to its environmental toxicity. Additional data would need to be collected at Fisherville Pond and other locations to determine this relationship(s).

2.1.12.2 Sediment Loading. Sediment loading is defined as the amount of sediment being transported downstream. No sediment loading studies have been performed in the Blackstone River watershed. In September 1992, the USGS published "Sediment Deposition in U.S. Reservoirs, Summary of Data Reported 1981-85." Based on sediment loading rates from other similar watersheds in New England, the range of annual sediment loading for the Blackstone is likely between 260 and 650 cubic yards per square mile (cy/sm). From previous New England District studies on watersheds with similar physical watershed characteristics within Massachusetts, an annual loading of about 400 cy/sm can probably be expected for the Blackstone River basin. During the height of industry in the watershed, sediment loading rates were probably much higher. However, it appears that sediment load to the river is decreasing despite increasing urbanization due to improved stormwater management practices and the decline of manufacturing in the region. In addition, sediment quality is believed to be improving.

2.1.12.3 Existing Sediment Volumes. Based on visual field observations, much of the storage behind most of the mainstem dams and some of the tributary dams has been lost to accumulated sediment. Table 8 summarizes, to the extent available, the best estimates of accumulated sediment behind many of the mainstem Blackstone River dams. Since much of this sediment has been accumulating for 100 to 200 years, many of these deposits are likely contaminated with metals, organics, and PCBs.

TABLE 8 - Estimated Accumulated Sediment in Pond Storage

Location	City/Town	Estimated Sediment Volume* (cy)
Quinsigamond Pond, Middle River	Worcester	20,000
Singing Pond	Sutton	260,000
Fisherville Pond	Grafton	780,000
Farnumsville Pond	Grafton	215,000
Riverdale Mill Pond	Northbridge	225,000
Rice City Pond	Uxbridge	525,000

*NOTE: For all locations except Quinsigamond Pond, volumes are taken from "A Sediment Control Plan for the Blackstone River," Joseph McGinn, 1981. Volume at Quinsigamond Pond developed from information in the Phase I Inspection Report and site visits. Based on review of pond geometry, areal extent of sedimentation observed, and reported depth of sediments, McGinn's volumes of sediment appear to be conservatively high, i.e. they may overestimate actual volumes.

2.1.12.4 Impacts of Dams and Impoundments on Sediment and Water Quality. Dams located on any river generally slow down the natural flow of the river sufficiently to allow suspended solids to settle within the impoundment. The degree of sediment build-up is dependent upon the amount of sediment within the river and the hydraulic and hydrologic characteristics of the impoundment. Therefore, impoundments may serve as sediment, toxic substance and nutrient sinks that can serve to clarify rivers downstream of the impoundments. Besides clarifying waters, removal of suspended inorganic solids from the water column, as may occur within impoundments, may also serve to remove organic compounds such as pesticides and heavy metals from the water column by sorption to the inorganic particles.

There are both beneficial and detrimental aspects of impoundments as it relates to sediments. Impoundments can benefit a river by removing toxic chemicals through sedimentation of particulates to which these chemicals are bound; however, these chemicals are not entirely harmless when on the bottom of the impoundment and there is potential that they could be resuspended during episodic high flow events, thereby reintroducing these toxic chemicals to the water column. Aquatic organisms may or may not be exposed to toxic chemicals in the water column, depending upon dissolved oxygen levels in the water. Those contaminants that may be released from the suspended sediments during high flow conditions undergo appreciable mixing with the waters of the overall system, therefore concentrations are likely to be minimal. The above discussion also applies, to a large degree, to the potential for reintroducing nutrients to the water column.

Since much of the usable sediment storage in the reservoirs has been filled, it appears that much of the incoming sediment load is passed downstream. Due to this fact, it is unclear whether the sediments will cap themselves, with the newer, cleaner, sediments being deposited on the older, more contaminated, deposits.

In the event of a dam failure at any of the mainstem dams, large amounts of sediment could potentially be carried downstream. Depending on inflows and the size of the breach, much of the accumulated sediment can be expected to be carried downstream in the initial flood wave. Immediate impacts from this would be re-introduction of older, more highly contaminated sediments to the water column and sedimentation in all slow moving river reaches, especially in the floodplains and within existing downstream impoundments. In addition, after the dam failure and prior to reconstruction of the dam, remaining bottom sediments will continue to move downstream due to higher riverine flow velocities in former impoundment areas. Likewise, bank erosion will be experienced in the absence of the dam.

2.2 Biological Resources

This section provides a general overview of the biological resources in the Blackstone River basin. Additional site specific information is provided in Section VI and Appendix E.

2.2.1 Vegetation

2.2.1.1 Wetland and Riparian Habitat. The USFWS National Wetland Inventory maps delineate wetlands and wetland community types based on the USFWS wetland habitat classification system on USGS quadrangle sheets. The maps are useful to identity large wetland systems and predominant wetland habitat types, however the scale of the mapping is too large to provide precise site specific information. A review of the USFWS inventory maps for the basin indicates that the predominant community types are:

- Broadleaf deciduous forest and forest/scrub-shrub
- Scrub-shrub and scrub-shrub/emergent
- Emergent
- Open Water

Species commonly occurring in each major habitat type are described below:

Forested: Forested wetlands in the Blackstone basin are typically dominated by red maple, and in rare occasions white cedar or black spruce. White pine is also common. Common understory species include highbush blueberry, arrowwood, common elder, swamp azalea, skunk cabbage, and cinnamon fern.

Scrub-Shrub: Common species include speckled alder, willows, sweet pepperbush, highbush blueberry, dogwoods, arrowwood, skunk cabbage, and cinnamon fern.

Emergent: Common species include cattail, purple loosestrife, woolgrass, soft rush, pickerelweed, smartweeds (*Polygonum* spp.) reed canary grass, *Phragmites*, other aquatic grasses, sedges, rushes, bullrush, spikerush, and burreed.

Open Water: Pondweeds (Potamageton spp.), water-shield, water lilies, and wild celery are common native species. The aquatic weed Eurasian water milfoil is common in eutrophic ponds, lakes, and impoundments. Open water habitat in many large lakes (lacustrine) is too deep to support submerged aquatics.

Riparian habitat in the Blackstone River basin is primarily wooded. Forested riparian areas are typically dominated by red maple. White pine and oak are common in drier locations. Common species in scrub-shrub riparian habitat include alder, dogwoods, willows, and buttonbush.

2.2.1.2 Upland Habitat. Undeveloped upland (non wetland) habitat in the Blackstone River basin is primarily forested. The basin lies in the "Central Hardwoods-Hemlock-White Pine" forest region. This region has a mixture of species common to more northerly or southerly areas. Until it was wiped out by the Chestnut blight late in the 19th century, American chestnut was the dominant tree. Currently, red, black, and white oaks, hickories, gray, yellow, and black birches, and maple are the major species, with red maple occurring in wetter sites. White pine and hemlock are the dominant evergreens.

Old fields and other open land is typically colonized by shrub species such as staghorn sumac, gray birch, and white pine saplings. Although some pasture is present, grassland habitat that is not grazed or regularly mowed is very rare.

2.2.2 Fisheries Resources

The existing historical and current information on resident fishery resources in the Blackstone River watershed in Rhode Island and Massachusetts is somewhat limited; however, a recent watershed fishery survey conducted by Rhode Island and additional site-specific fishery surveys conducted by Massachusetts, respectively, have provided a current basin wide evaluation of the status of the respective fisheries.

Based on a review of the existing fishery survey data, the mainstem Blackstone and its major tributaries presently support an improving recreational warm water fishery throughout the basin and a put and take stocked trout fishery in selected portions, e.g. lower Blackstone River. Wild brook and brown trout fisheries exist only in the upper reaches of the basin where suitable coldwater fish habitat and high dissolved oxygen levels persist. A detailed summary of the results of the fishery surveys conducted from the 1970s to the present is presented in Appendix E.

Previous studies show that fisheries resources in the Blackstone and the major tributaries are recovering from a severely degraded condition. Data collected during the 1970s suggested that water quality parameters were indicative of polluted conditions, and biological studies showed a corresponding reduction in abundance and diversity of aquatic organisms. Prior to the enactment of the Federal Water Pollution Control Act Amendments of 1972, the Blackstone River and its tributaries received numerous untreated wastewater effluents resulting in degraded water and sediment quality. Studies in the 1980s and into the 1990s suggested the beginning of river biota recovery resulting from improved water quality in response to the addition and upgrading of wastewater treatment plants, although toxicants in sediment and in fish tissue continue to pose concerns. The recovery of the basin is expected to benefit by the enactment and promulgation of environmental protection acts and implemention of regulations (e.g. Wetland Protection Act/regulations) which include the protection of riparian (riverfront) areas in order to preserve the natural integrity of rivers and adjacent land. Natural riverfront areas are critical to maintaining a thriving fisheries.

The earlier surveys indicated that the fishery resources present in the mainstem Blackstone River and major tributaries were generally typical of warm water habitats, however, they included only species capable of surviving in poor quality waters resulting in resident fish populations that were undesirable for sport fishing. The more recent surveys, including those of the macroinvertebrate communities, reflect improvements in water quality. While the current fishery is still characteristic of warm water habitats, there is a greater number of recreational game species present, including yellow perch, white perch, largemouth bass, smallmouth bass, black crappie, chain pickerel, and northern pike, all typical of better water quality conditions, and all providing good recreational fishing opportunities.

To further investigate the status of the fisheries resources, the Corps conducted a limited fish community survey in Fisherville Pond as part of this Reconnaissance Investigation to supplement similar information collected in a July 1992 survey by MADFW. There were two main objectives of the Corps survey. The first was to provide current fisheries data to qualitatively assess the status and subsequent needs of the existing fishery. The second was to determine the appropriate representative fish receptors (assessment endpoints) for a preliminary baseline risk assessment on Fisherville Pond water quality and sediments in order to determine if existing contaminant concentrations pose a significant risk to the fish community. Results of the site specific fishery survey and corresponding risk assessment for Fisherville Pond, which is considered representaive (i.e. typical) of other impoundments in the basin, can be applied to the existing resident fisheries on a basin wide basis.

The results of the two limited fisheries surveys concluded that Fisherville Pond supports a moderately diverse and abundant warm water fish community, similar to that reported for other impoundments and ponds within the Blackstone River watershed in Massachusetts and Rhode Island (see Appendix E). Since moderate numbers of fish were collected in Fisherville Pond, it is evident that the existing surface water and sediment quality do not cause significant acute effects to fish that are readily observable (e.g. fish kills). Apparently, the contaminant concentrations in the water and sediment have not adversely impacted reproduction and recruitment of fish, since juveniles (young-of-the-year) as well as adults of two species (bluegill and largemouth bass) were collected during the fall 1996 survey. However, the potential level of significance of any direct adverse impacts to any of the species present cannot be definitively determined by existing data.

Based upon a review of the limited survey data and analyses, it is apparent that we do not know enough about the fish population of Fisherville Pond and the basin, in general, to predict direct effects of existing water and sediment quality and water level management to the fish community. Accordingly, more intensive surveys and analyses (e.g. age and growth studies) of selected species need to be conducted.

Im summary, the dominance of the current fish population by more pollution tolerant species (e.g. white sucker, golden shiner and carp) indicates that the Blackstone River system is still somewhat degraded by a combination of water and/or sediment quality. However, the presence in good numbers of less tolerant species (largemouth bass, yellow perch, and bluegill) demonstrates strong potential for the development of a more balanced fish community concurrent with improving habitat conditions.

2.2.3 Anadromous Fisheries

Historically, the Blackstone River supported spawning runs of anadromous species of fish. Each spring adult American shad, river herring (alewife and blueback herring), and Atlantic salmon would ascend the river to spawn. Unfortunately the extensive construction of dams for water power in the 1800's interrupted and eliminated these runs. The first dam on the Blackstone was constructed in 1793 to generate power for Slaters Mill despite protests of upstream farmers and fishermen. The effect of the dam was to destroy the anadromous fishery migration.

Atlantic salmon once constituted a large portion of the commercial catch in Narragansett Bay. However, the bay fishery was very short-lived, completely collapsing by 1869. The collapse can be attributed to the salmon's loss of access to suitable spawning grounds in upper reaches of Bay tributaries. All tributaries to the Providence and Seekonk Rivers, including the Blackstone, were dammed by the early 1800s to provide water power for the region's burgeoning industrial needs. This closing of the tributaries would have severely, if not completely, eliminated access of salmon to their historical spawning beds in the upper tributaries.

Alewives, another anadromous fish species, commanded an extensive fishery in Narragansett Bay from the mid-1800s to the turn of the century. But by the early 1900s this commercial fishery was declining rapidly, and it was essentially abandoned by the 1930s. This species, like the salmon, travels up the estuary to spawn, but it is not as reliant as salmon on gaining access to the upper reaches of tributaries to successfully reproduce. Although damming of tributaries in Narragansett Bay may have negatively influenced alewife stocks, the fishery's failure is generally attributed to overfishing. During the spring alewife runs, fish traps were placed throughout Narragansett Bay, particularly in the East and West passages and the mouth of Sakonnet Bay. These fish traps were often placed so densely that it was virtually impossible for any alewives to reach the upper bay without becoming lodged in one. Alewives have not been fished on a commercial basis in Narragansett Bay waters since the fishery's collapse. Since the late 1950s, however, alewives have begun to return to Narragansett Bay in increasing numbers, and have often been noted in the Providence and Seekonk rivers. Spawning now occurs in some of the lower and coastal tributaries of the bay which remained accessible, and the species appears to be re-populating itself as a springtime visitor to Narragansett Bay waters.

It is apparent that the collapse of Narragansett Bay fisheries for anadromous species is not directly attributable to water quality degradation in the estuary and tributaries. Overfishing took a rapid toll on the populations of these fishes as they moved through the bay to spawn, and loss of access to historic spawning areas due to the construction of dams, at least for salmon, prevented the rapidly depleted adult stocks from replacing themselves. In the case of the alewife fishery, water quality degradation in the Providence and Seekonk Rivers may have caused a loss of suitable spawning habitat, but extraordinary fishing pressure apparently was the main cause of the extinction of the commercial fishery in Narragansett Bay.

Recent improvement in water quality along with advancements in fishway technology indicate that restoring populations of American shad and river herring to the lower reaches of the Blackstone River system is possible. Restoration of Atlantic salmon would be more difficult since historic salmon spawning and nursery habitat areas located in the upper tributaries of the Blackstone River are inacessible due to numerous dams on the mainstem river and tributaries. In addition, most of the tributary headwaters, are impounded resulting in feeder streams too warm for salmon survival. Currently, Atlantic salmon are not considered as a viable restoration target species for the Blackstone River based upon the analyses and proposed actions in the "Final Environmental Impact Statement (FEIS) 1989-2012: Atlantic Salmon Restoration in New England" issued by the USFWS in 1989. The Blackstone River was not included among the 28 major rivers in New England that contained significant Atlantic salmon populations in pre-colonial times and consequently has not been targeted for restoration in the FEIS.

While the economic benefits of a commercial and/or recreational fishery can be mathematically estimated, it is difficult to calculate the ecological value of anadromous fish restoration. Reintroduction of anadromous fishes to their previous spawning grounds will have a positive effect on the ecology of those freshwater systems. In freshwater areas where herring have been restored, studies show that resident fish populations were enhanced. The juvenile herring produced in the spawning run serve as a food supply for bass and other resident species. All life stages of anadromous herrings are important forage for many freshwater and marine fishes; in addition, birds, amphibians, reptiles, and mammals have also been documented as predators. The mortality of anadromous alewives provides an important source of nutrients for headwater ponds.

2.2.4 Other Aquatic Resources

Bottom-dwelling ("benthic") species of invertebrates are known as "benthos" or "benthic macroinvertebrates" in an aquatic ecosystem. Benthic macroinvertebrates are those organisms that can be seen with the naked eye and are typically the subject of all benthos investigations. Benthic macroinvertebrates include organisms which inhabit the substrate surface or burrow within sediments for food or shelter. The occurrence, density, and distribution of invertebrates has been suggested as indicative of the overall water quality of aquatic ecosystems. Furthermore, benthic macroinvertebrates function as excellent indicators of local environmental conditions, with their limited migration patterns and relatively short larval life cycles. Natural factors may also influence the type and abundance of benthic macroinvertebrates on a seasonal basis. Natural factors such as water temperature, dissolved oxygen, anaerobic sediments, organic loading to the system, and chemical contamination are all important in structuring benthic communities. Macroinvertebrate communities are inherently variable, particularly seasonally, but also on shorter (e.g. monthly) and longer (e.g. annual) scales. In addition, macroinvertebrate communities are spatially variable, often occurring in "patches" of varying size. Consequently, the use of macroinvertebrates as an assessment tool must be approached cautiously. A considerable level of effort is necessary to obtain meaningful information that incorporates natural and spatial variation.

Benthic macroinvertebrates feed primarily on aquatic vegetation (e.g. periphyton, submerged aquatic vegetation) and detritus (e.g. coarse particulate organic matter as leaf litter) and in turn become one of the lower trophic levels of the riparian/aquatic food chain. Benthic invertebrates are widely recognized for the important role they play in the aquatic food web. These creatures are eaten by larger invertebrates, crustaceans, finfish, wading birds, amphibians, turtles, and even some mammals. Therefore, a healthy benthos is essential to a healthy aquatic ecosystem. Benthos are most affected by toxic substances, water-borne sediments, and loss of microhabitat and vegetation. The benthic quality of an aquatic ecosytem is a yardstick by which to measure/assess current water quality and habitat quality (e.g. substrate particle size) and the success of any effort to improve these parameters.

Results of the Massachusetts DEP's comprehensive biomonitoring survey of the Blackstone River and selected tributaries in June 1985 revealed benthos that indicated some of the worst water quality to be found in Massachusetts inland streams. However, data on benthic macroinvertebrate populations collected in 1991 during the comprehensive Blackstone River Initiative, compared with data collected in 1985, showed improvements at most stations. Additional improvements in benthic macroinvertebrate populations are expected due to basinwide efforts to reduce non-point source pollution and continued improvements in wastewater treatment facilities, e.g. the Upper Blackstone Water Pollution Abatement District added dechlorination of its wastewater in the fall of 1993.

2.2.5 Wildlife Resources

Despite hundreds of years of development which resulted in the loss of perhaps one-third of original wetland habitat, considerable loss of stream habitat, fragmentation of remaining riparian habitat, introduction of invasive non-native plant and wildlife species, and the discharge of tons of waste, the Blackstone watershed continues to provide habitat for hundreds of wildlife species. A few species such as striped skunk, coyote, cowbird, and blue jay, have thrived under human occupation. Many of the remaining species, however, have undoubtedly declined in population and range. An unknown number have been extirpated. Some species such as the spotted turtle and eastern box turtle may be in serious decline and in danger of being extirpated from their remaining habitat in the basin.

Many of the basin's mammals, amphibians, reptiles, and birds strongly depend on wetland or riparian habitat. Among the more common large mammals occurring in the basin are white-tailed deer, raccoon, striped skunk, Virginia opossum, eastern cottontail, gray squirrel, red fox, coyote, and woodchuck. Species with an even greater territory occasionally noted in the basin include fisher, moose, and black bear.

Common amphibians include redback salamander, red-backed newt, eastern American toad, gray treefrog, northern spring peeper, green frog, and wood frog. Populations of many amphibians are in decline in the United States, but their status in the Blackstone basin is unknown. Common reptiles include snapping turtle, painted turtle, and eastern garter snakes.

More than 200 species of birds have been seen in the Blackstone River basin. About one-half of these are strongly wetland dependent. Waterfowl are discussed in the following section.

2.2.6 Waterfowl

Wetlands, lakes, impoundments, and slow moving rivers and streams in the Blackstone River basin provide habitat for resident (nesting) and migrating waterfowl. The principal nesting species are mallard, wood duck, and Canada Geese. Black duck also breeds in the basin, but nesting populations have declined significantly during the last several decades, as is the case elsewhere in the Northeast. Migrants include mallard, wood duck, Canada goose, black duck, mallard and black duck hybrids, green-winged teal, blue-winged teal, pintail, American widgeon, common and hooded mergansers, bufflehead, scaup, common goldeneye, grebes, ring-necked duck, and American coot. Waterfowl habitat provided by the Blackstone basin is nationally significant since the area has been identified as an important flyway for migratory waterfowl by the North American Waterfowl Management Plan.

The most important waterfowl habitat areas in the basin are several large impoundments on the Blackstone River. These include Fisherville Pond, Riverdale Pond, and Rice City Pond in Massachusetts, Londsale Pond, Valley Falls Pond, Manville Pond, and Ashton Pond in Rhode Island. Lackey Pond on the Mumford River in Massachusetts also provides significant waterfowl habitat. These impoundments are valuable to waterfowl because they have extensive areas of shallow open water habitat interspersed with emergent marsh which provide breeding and brood habitat for resident species, and resting and feeding habitat for migrating waterfowl passing through the area in the spring and fall seasons. Significant nesting habitat for waterfowl, especially mallard, a cosmopolitan breeder, is also provided by numerous other smaller lakes, impoundments, ponds, slow moving streams, and wetlands situated throughout the basin.

Historically, wet meadow and shallow marsh habitat at Fisherville, Rice City Pond, and Lackey Pond provided premier waterfowl habitat (see MADFW sampling data from the late 1960's through 1990's provided in Appendix E). Fisherville Pond and Rice City Pond were considered the most productive areas in the state, especially for mallards and black ducks. Wood duck were also abundant. Much of the habitat value of Fisherville Pond for breeding and migrating waterfowl was lost, however, after a drawdown in the early 1980's destroyed about 10 acres of the most productive emergent marsh/open water habitat at the site (see Section 6.1).

The Valley Falls Marshes are considered to be the most valuable waterfowl habitat in northern Rhode Island. This area provides nesting habitat for waterfowl and several of the rarer marsh-nesting birds including the Least Bittern and Sora Rail. The Valley Falls Marshes also provide feeding and resting habitat for migratory waterfowl which can number 500-1000 birds during spring and fall migration periods.

Waterfowl production values for the entire Blackstone River basin are unavailable. Recent (1989-1995) trends for the 11 state Atlantic flyway region (including Massachusetts) indicate that mallard, wood duck, and black duck populations are fairly constant while the Canada goose population is increasing dramatically. With the inception of a hunting season for resident Canada geese in Massachusetts, goose populations in the state are expected to decline.

2.2.7 Special Concern, Threatened, and Endangered Species

The Massachusetts and Rhode Island Natural Heritage Programs have identified numerous sites in the Blackstone River basin that are known or thought to provide habitat for rare or protected plants and animals. With the exception of transient peregrine falcons no Federally listed species occur in the study area. Several species of Federally threatened or endangered sea turtles are known to occur as transients in Naragansett Bay.

2.2.8 Significant Natural Areas

The Blackstone River basin contains dozens of significant natural areas. Many of these have been protected by local communities as town conservation land. The BRVNHCC has recently completed a list of significant natural areas in the watershed.

2.3 Recreation Resources

The Blackstone River watershed contains a large number of recreational resources and opportunities, resources enjoyed by residents of the watershed as well as the greater populations of the nearby cities of Boston and Providence. The watershed's recreational opportunities include boating, canoeing, and fishing, as well as swimming, hiking, biking, picnicking, and other related activities at the various town, state, and Federal parks along the river. The historical and cultural resources of the watershed, particularly the historic mill buildings and mill villages along the Blackstone River, also provide recreational and tourism value.

2.3.1 Public Parks

Significant public parks along the Blackstone River and tributaries include the following: Blackstone River and Canal Heritage State Park in Northbridge and Uxbridge, Massachusetts; West Hill Dam and Park on the West River in Uxbridge; Blackstone Gorge State Park in Blackstone, Massachusetts and North Smithfield, Rhode Island; Blackstone River State Park in Lincoln and Cumberland, Rhode Island; and the Valley Falls Marshes and Lonsdale Marsh area in Central Falls, Cumberland, and Lincoln, Rhode Island.

The Blackstone River and Canal Heritage State Park in Northbridge and Uxbridge stretches along the mainstem of the Blackstone River from Plummers Landing in Northbridge to Stanley Woolen Mill in Uxbridge. The park is a Massachusetts state park, run by the MADEM. The park has a visitors center, and contains Rice City Pond, a large pond very popular for canoeing and other small boat usage, but which has limited other usage because of sediment contamination. The Blackstone River itself provides additional boating and canoeing opportunities in the park. The park also contains an intact, watered canal segment and towpath, from the old canal and towpath which used to run along the entire river from Pawtucket to Worcester. When it was fully operational in the 1830's and 1840's, the canal was used to transport goods up and down the river, supporting the many manufacturing industries that were located along the river. The existing canal segment in the Blackstone River and Canal Heritage State Park is currently used for canoeing, and the towpaths for hiking. The park also contains a number of trails for hiking, biking, and horseback riding.

West Hill Dam and Park is located in Uxbridge on the West River, a major tributary of the Blackstone River, and is owned and operated by the Corps of Engineers. The park contains Harrington Pool for swimming, picnic facilities, hiking and mountain biking trails, a nature trail, fishing in ponds and in the West River, and hunting opportunities.

The Blackstone Gorge and State Park is located in Blackstone, Massachusetts and North Smithfield, Rhode Island, and is owned and operated by both the MADEM and RIDEM. This is currently a less developed park, with no formal visitors center. The park contains a hiking trail, an unmarked canoe put-in location, and a temporary Blackstone Valley Explorer Riverboat landing site above the Gorge for riverboat trips from the gorge area to points upstream. Both MADEM and RIDEM have plans for land acquisition to expand the park, and the provision of additional resources for recreational use.

The Blackstone River State Park is located in Lincoln and Cumberland, Rhode Island, and is operated by the RIDEM. The park stretches along the mainstem of the Blackstone River from the village of Albion through the village of Ashton to the village of Lonsdale. Features of the park include three miles of watered canal and towpath, the Loop Trail at Lincoln Wellfields for hiking and nature observation, the 20-acre Ashton Meadows, hiking trails between Ashton and Albion, hiking on the canal towpath, and canoe access sites.

The Valley Falls Marshes and Lonsdale Marsh area, which includes wetlands located in the towns of Cumberland, Lincoln, and Central Falls, Rhode Island, contain some of the most valued wetland habitat in Rhode Island. The area is a combination of state-, city-, and town-owned lands, and includes various marshlands along the Blackstone River. Recreational uses of the area include nature and wildlife watching, fishing at the John Street bridge, and canoeing. The park area includes a canoe access site and a Blackstone Valley Explorer Riverboat landing site.

There are a number of smaller city and town-owned public parks along the Blackstone River, particularly in Rhode Island. Riverfront parks in Woonsocket include Cold Spring Park, Costa Park, The Island, and River Island Park. These parks contain a mixture of open space, riverfront access, and ballfields. There is some town-owned land in the park known as the Wilderness Area in Central Falls, Cumberland, and Lincoln, and there is Pierce Park and the Riverwalk in the city of Central Falls.

The town of Grafton, Massachusetts owns two parcels of land in the vicinity of Fisherville Pond which were deeded to the town as open space. There is unofficial parking at one of the sites, and off-road parking at the other. While these parcels are not an official town park or town beach, they do support public use of Fisherville Pond, use which includes fishing, canoeing, and other small boat usage. In the area of Farnumsville in Grafton, the town has been working with the BRVNHCC to establish an official, deeded canoe access point at Farnumsville.

Future park expansion is also planned along the Blackstone River. MADEM has plans to develop a park at the historic Millville Lock in Millville, Massachusetts while RIDEM is negotiating to purchase the Lonsdale Drive-In site in Lincoln, Rhode Island. This area provides excellent fishing opportunities and could provide canoe access. RIDEM may also be improving the recreational opportunities at the Wilderness Area in Cumberland in the near future, by improving boat access, improving trails, and providing a better observation point in the wetland.

2.3.2 Canoe Usage

Currently the Blackstone River and tributaries are commonly used for canoeing. The mainstem river contains a variety of canoeing opportunities, including some portions good for flatwater canoeing, particularly in the canals, and many other portions good for quickwater canoeing. In addition, there is the opportunity for whitewater canoeing in the Blackstone Gorge several times during the year, for a half-mile stretch from the Tupperware Dam to the confluence with the Branch River. The BRVNHCC has taken an active role in formalizing and promoting canoe usage of the river, and has published a canoe guide. The canoe guide describes specific canoe trips along the length of the Blackstone River. The guide contains the length of each trip, the best put-in and take-out sites, and the difficulty level of canoeing in each reach. The guide also identifies dams along the route, describes how to best portage around each dam, and, most importantly, identifies any potential hazards, particularly dangerous dams or dangerous whitewater areas to avoid. The different canoe put-in and take-out sites include primarily privately owned, informal sites where the owners allow usage. In all, there are 36 canoe access points along the Blackstone River between Worcester and Pawtucket.

In general, the many dams along the Blackstone River do not excessively impede canoeing on the river. However, there are three dams near the southern end of the river around which portage is possible but difficult and potentially dangerous. The first is the Pratt Dam in Lincoln, just north of Lonsdale. The dam is dangerously high, and portage around the dam is extremely difficult. The canoe guide recommends usage of the canal instead of the river in this stretch to avoid this dam. The second difficult dam is the Valley Falls Dam at Broad Street in Central Falls. Portage around this dam is particularly long and difficult, with a long carry and a steep slope. The third difficult dam is the Elizabeth Webbing Mills hydropower dam in Central Falls-Pawtucket. The take-out at this dam is not a problem, but the put-in below the dam requires carrying the canoe down very steep slopes.

The BRVNHCC is currently working to improve canoe access along the Blackstone River. Most of the 36 current canoe access points are on private property, are unmarked, and have little or no formal parking. The commission has plans to put up formal signage at each access point, to develop adequate parking facilities, and to construct erosion control measures and landscaping where needed. Most of this work is currently planned to be coordinated and completed by the BRVNHCC over the next two or three years. In a few locations the MADEM or the RIDEM has responsibility for the improvements.

2.3.3 Canal Usage

There are several segments along the Blackstone River where there are existing remnants of the old canal and towpath which ran along the entire river in the mid-1800's. There are two long segments which are currently watered, as they were in the 1800's. The first stretches from Northbridge, Massachusetts to Uxbridge, Massachusetts, within the Blackstone River and Canal Heritage State Park. The second watered segment is in Lincoln, Rhode Island, and stretches from the village of Albion to the village of Lonsdale, located within the Blackstone River State Park. These canal segments have historic value, since they show what the canal looked like when it was fully operational, and they also have recreational value, since the canals are used for canoeing and fishing and the towpaths are used for hiking. The flatwater canoeing available in the canals is particularly important since the mainstem of the river provides primarily quickwater canoeing opportunities, not suitable for all skill levels.

The Blackstone Canal Conservancy, a non-profit organization, is working to restore and preserve the Blackstone River Canal. The Conservancy has three general goals: to conserve remaining open space; to preserve remnants of the canal, old locks, and towpaths; and to educate the public about the canal and its historic usage. In order to achieve these general goals, the Conservancy has several more specific goals at this time. The first is to protect a number of the longer canal towpaths, preserving them as open space and allow for their usage as hiking trails. Specific stretches along the river that the Conservancy is interested in preserving include a 3.5 mile stretch within the Blackstone River Canal and Heritage State Park in Northbridge and Uxbridge; a segment at the Millbury-Worcester town line; a segment from Howe Street in Millbury to Wilkinsonville in Sutton; a segment from Route 122A in Grafton to Sutton Road in Northbridge; a segment from Route 122 in Uxbridge to Millville; a segment from Woonsocket to Manville in Lincoln; and a segment from Manville to Lonsdale in Lincoln within the Blackstone River State Park.

The Canal Conservancy also wants to restore the historic "Millville Lock", located at the end of Hope Street in Millville, Massachusetts. The lock is currently located on land owned by the MADEM. The Conservancy wants to make the lock operational, and use it for demonstration and educational purposes.

The Conservancy also would like to construct and run a horse-drawn barge in the canal, for an actual, operational re-creation of how the canals were used. The route for the horse-drawn barge would be located within the Blackstone River and Canal Heritage State Park, and would run from Riverbend Farm to the Stanley Woolen Mill, all in Uxbridge. A group called the "Heritage Homecoming Group" is working to try to make this idea a reality.

2.3.4 Blackstone Valley Explorer Riverboat

The Blackstone Valley Tourism Council, a non-profit organization headquartered in Pawtucket, Rhode Island, operates a riverboat in the Blackstone Valley during the spring, summer, and fall months. The riverboat, called the Blackstone Valley Explorer, provides opportunities to learn about the history of the river and the industries along the river, provides opportunities for nature viewing, and provides general recreational value. The Explorer seats 49 passengers, is 33 feet long and has a draft of 10 inches. The vessel is covered so that it can be used in a variety of weather conditions. In each year since the vessel began operating, ridership has increased, and the number and type of river excursions offered has been expanded and refined to best suit the passengers and the attractions along the river. In total, the Explorer has carried 75,000 passengers since it began operating in 1993. Annual ridership was 22,000 in 1995, and was projected to increase to 30,000 in 1996.

Since the tourism council currently has only one vessel, the Council moves the vessel up and down the river to different locations during different times of the year. In 1996, the riverboat operated along seven different stretches of water in the valley, four of which were on the Blackstone River. These four stretches include a trip from the Blackstone Gorge north to the Blackstone-Millville line in Massachusetts; a trip called "Thunder in the Mist" in Woonsocket from Market Square north to Blackstone just over the state line; a trip through Valley Falls and the Wilderness Area in Central Falls, Cumberland, and Lincoln, Rhode Island; and a trip from Slater Mill Pond north to the Elizabeth Webbing Dam in Central Falls. Other trips not on the Blackstone River include operations at the Slatersville Reservoir in North Smithfield, Rhode Island, operations on the Pawcatuck River, tours of the Seekonk River in Pawtucket south of the Main Street Bridge, and a tour of the East Providence waterfront. In all, the riverboat generally operates at each location for several weeks, after which the boat is moved to operate at another location.

2.3.5 Bikeway Development

There are currently plans to construct and designate a formal bikeway along the Blackstone River. The bikeway is being planned and will be constructed by a combination of agencies, including the MADEM, the Massachusetts Highway Department, and the RIDEM. The route for the bikeway in Rhode Island at this time has been finalized. Most of the route will run through existing park land along the river, and in some cases along the top of flood control dikes that are part of the Corps of Engineers Local Protection Projects. The total length of the bikeway route in Rhode Island is 17.1 miles, and it is estimated to have a total construction cost of $17 million. Completion of the Rhode Island segment is expected within 5 years.

The route for the bikeway in Massachusetts is still being finalized and revised, taking into account different concerns and interests. MADEM recently completed a detailed study of the proposed bikeway with various route alternatives, out of which a recommended bikeway route was developed. In some locations the recommended route runs directly along the river, in other locations the route is located on a nearby road not directly along the river. The total length of the current bikeway route in Massachusetts is 26 miles, and it is estimated to have a total construction cost of $10 million. MADEM does not currently have the resources to fund this effort. As a result, the agency expects to construct the bikeway in small portions, and to do work in conjunction with the Massachusetts Highway Department and local towns. MADEM hopes to construct one portion of the bikeway in the near future, a 3 mile stretch on land MADEM already owns on an old railroad right-of-way in Blackstone and Millville. Other lands on the preferred route would have to be acquired. Since there are many uncertainties regarding land acquisition and availability of funding, the construction of the bikeway in Massachusetts will likely be a long-term project, and the exact route will likely evolve as the project develops.

2.4 Cultural Resources

It may be correctly stated that the Blackstone River Valley is itself a cultural resource. There is most likely no other area in New England exhibiting as great a wealth of unique, observable and largely intact historic and archaeological remains throughout its stretch. The BRVNHCC has identified several general historic resources including historic farms and hilltop villages, mill villages, mills, mill housing, individual structures, roads, canals, and the railroad. Congress has affirmed the significance of the watershed through its designation of the BRVNHCC as indicated earlier. As there are literally hundreds of documented historic, archaeological and architectural properties within the Valley, for purposes of the current study, these resources will be summarized to discuss only the most significant or those to be the most likely affected by proposed project plans. These will include National Historic Landmarks, Districts and individual properties as well as potentially eligible National Register properties.

a. Documented Cultural Resources - Rhode Island. Research at the Rhode Island State Historic Preservation Officer (SHPO) facilities in Providence has yielded the following information. Table 9 lists only the more prominent sites, and should not be considered exhaustive. Additional sites and properties are documented for the study area. Further research would be required in a later planning stage when final alternatives have been designed in order to conclusively document all affected properties. Beginning at the Main Street Dam

Birthplace of the American Industrial Revolution

The landscape of the Blackstone River valley was largely agrarian during the early part of the 18th century. However, by the latter part of the century, regional center emerged in Providence and Worcester and, on a smaller scale, in the northern Valley communities of Sutton and Mendon where transportation, agriculture, and mill sites contributed to their prosperity. Following the Revolution, Providence emerged as the capital and commercial center supplanting Newport. In these years, the Valley still retained its agrarian character, however cottage industries and small manufacturing sprang up including hat-making, shoemaking, wood processing and metal products. However, these emergents paled in comparison to what is termed "the Second Revolution" in the area (BRVNHCC 1989:4). Samuel Slater, formerly a manager at the Arkwright mills in England, came to the United States and helped to establish the first successful water-powered textile mill in Pawtucket. Together with Providence merchant, Moses Brown they produced a working set of mechanical spinning machines in 1790 and in 1793 this thriving operation moved into larger facilities which are today known as the Slater Mill National Historic Site, a National Historic Landmark. "More than any other single event, this successful transplantation of the Arkwright factory system can be said to mark the birth of the American Industrial Revolution and the complete transformation of American life and character." (BRVNHCC 1989:4)

By 1814, water-powered mills occupied all the readily available sites in the Blackstone Valley. Cotton and wool textiles predominated, however, other industries such as edge tools, textile machinery, firearm and paper manufacture began to develop on the factory system. The pattern of the Valley landscape was also altered by the proliferation of mills. Formerly where dispersed farms and hilltop communities were the norm, now a series of riverside mill villages emerged. These communities centered around the many-windowed, multi-storied, frame, stone and brick factories and contained uniform and adjacent rows of workers' housing, company stores, and eventually, schools, churches and other community-related structures. These villages were the densest concentration of industry in the Blackstone Valley, however, they still managed to maintain their rural character amongst it all.

The mills of the Blackstone Valley were organized according to the Rhode Island System which is noted by small, privately financed mills, the use of family labor and the development of
entire mill villages with housing, schools, churches, as well as the place of employment. The beginning of wage labor as contrasted from the labor to produce products for sale.

The idea for a canal developed as early as 1796 by Providence merchant John Brown who was attempting to divert the trade of central Massachusetts away from Boston to the port of Providence. In this regard, a Providence Plantations Canal Company was established in 1796. In response, Boston submitted a counter proposal for a canal linking Boston to Worcester. Neither canal was approved and the matter rested. It was not revisited until 1822 when a survey of investigation was completed. The route would follow the River for

Birthplace of the American Industrial Revolution (continued)

the most part, except at Saylesville where it diverged into the Moshassuck River to connect to the Port of Providence. In 1825, a combined Massachusetts and Rhode Island entity, the Blackstone Canal Company formed and funding was secured from subscribers for the construction of the canal. Excavation begin in 1824 and was completed in 1828 when the Lady Carrington arrived in Worcester after having traveled the length of the Canal. The Blackstone Canal was an instant, albeit short-lived success with the savings on the transport of freight to be well worth the cost (Conley 1982:1-3).

However, in 1835, the Boston and Worcester Railroad was completed, thereby sealing the fate of the Blackstone Canal and returning Boston as the major port of Worcester County trade. The inaugural train between Providence and Worcester was chartered in October of 1847 and the last toll collected on the Canal was in November of 1848. Several reasons are posited for the failure of the canal: the presence of either high or low water in the riverbed portions of the Canal impeded travel; ice during the winter months, and drought which made water scarce for use in the locks. Overall, the effect of the Canal on the Blackstone Valley was positive economically for the communities along its path, in particular Uxbridge and Worcester. A proliferation of mills and manufactories developed along with the accompanying villages (Conley 1982:3-4).

The height of the Blackstone River Valley prosperity came between the Civil War and World War I as reflected by the magnificent mills and factories built during the period and burgeoning of other industries besides textiles including rubber products, wire, and various edge tools. It was at this time that the Blackstone River was known as "the hardest working river in America" and the period characterized as the golden age of American industry. The increased prosperity had its negative results as well most amply seen in the current pollution of the river (BRVNHCC 1989:7).

Following World War I, most textile jobs and industry relocated South for lower costs and a more conducive climate resulting in a severe economic decline and the Great Depression. Mills continued to close and population decreased at a steady rate. A short respite occurred during World War II, however the trend was by now apparent. Several exceptions to the rule contributed to wartime prosperity in producing shoes, boots, textiles, and naval shipbuilding (BRVNHCC 1989:8).

Since the mid-1980's and Congress's National Heritage Corridor designation, the Blackstone Valley and its residents have seen a renewed interest and cultural revival in the revitalization and preservation of the significant historic, cultural, and natural resources which make up their communities and which reflect the major contributions which the Blackstone River Valley and its residents have made to American life over the last 350 years (BRVNHCC 1989:8).

in Pawtucket and proceeding upstream, the Blackstone River watershed has the following resources and designations:

Table 9 - Documented Cultural Resources in Rhode Island

Documented Resource	City or Town	National Register listing
Main Street Bridge and Dam	Pawtucket	Potentially Eligible to National Register
Old Slaters Mill National Historic Site	Pawtucket	National Historic Site
Central Falls Mill National Register Historic District	Central Falls	National Register listed
Valley Falls Mill	Cumberland side	National Register eligible
Valley Falls Mill	Central Falls side	National Register listed
Valley Falls Historic District	Central Falls and Cumberland	Potentially Eligible to National Register
Saylesville National Register Historic District	Lincoln	National Register listed
Lonsdale National Register Historic District (includes Lonsdale Village HD)	Cumberland and Lincoln	National Register listed
Blackstone Canal National Register District	From Providence, RI to Massachusetts border	National Register listed (includes canal trench, towpath, berm and related engineering features such as masonry walls, spillways, basins and bridge footings
Limerock Village National Register Historic District	Lincoln	National Register listed

Documented Resource	City or Town	National Register listing
Berkeley Mill Village National Register Historic District	Cumberland	National Register listed
Ashton National Register Historic District and Old Ashton Historic District	Cumberland	National Register listed (Ashton Viaduct - Potentially Eligible)
Albion National Register Historic District	Cumberland and Lincoln	National Register listed
Mammoth Mill/Samac Mill site	Woonsocket	Potentially Eligible for National Register
Glenark Mill	Woonsocket	Potentially Eligible or Eligible to National Register
Woonsocket Downtown, Riverfront and Depot Square Historic Districts	Woonsocket	Potentially Eligible to National Register

b. Documented Cultural Resources - Massachusetts. Table 10 presents a partial listing of the most significant or well-known National Register properties in Massachusetts. This list is not all-inclusive and further review will be required after alternatives are selected. Archaeological resources are not included here. National Register and National Register eligible properties are listed in Table 10.

Table 10 - Documented Cultural Resources in Massachusetts

Documented Resource	City or Town	National Register listing
Blackstone Canal National Register District	From Worcester, MA to the RI border	National Register listed includes canal, canal trench, towpath, berm and related engineering features such as masonry walls, spillways, basins and bridge footings. In addition, dams and reservoirs which were created as a result of the Canal and locks (Millville Lock) are related and contributing properties of the historic district designation
Blackstone Manufacturing Company National Register Historic District	Blackstone	National Register listed
Farnum's Gate National Register Historic District	Blackstone	National Register listed
Fisherville National Register Historic District	Grafton	National Register listed. This district includes the village, its factory, residences, public buildings and commercial structures. Also included are the mill, dam, and Blackstone Canal remnants including its towpath, a culvert, lock and control gate.

Documented Resource	City or Town	National Register listing
Farnumsville National Register Historic District	Grafton	National Register listed
Ironstone Mill Worker Housing and Cellar Hole	Uxbridge	National Register listed

c. Significance of National Register Listings. The National Register of Historic Places is a database of historic, archaeological or architectural properties of local, State, and National significance maintained by the Secretary of the Interior. Properties on the National Register are evaluated and nominated on the basis of specific criteria known as National Register Criteria (36 CFR 60). Under Section 106 of the National Historic Preservation Act of 1966, as amended, Federal agencies are required to assess the effects of any Federally funded, licensed, or permitted undertaking on properties listed in or eligible to be listed in the National Register. This assures that cultural resources impacts are considered early in the planning process and that time and funding are available for proper surveys and mitigation, if required. Prior to the implementation of any undertaking which may impact resources listed or eligible for listing in the National Register, Federal agencies must show evidence of developing and evaluating all other prudent and feasible alternatives that avoid adverse impacts to these significant cultural resources. Project design alternatives must take into account the significance of these resources early in the planning process and avoid adversely affecting the important historic and archaelogical resources of the project area at all costs.

d. Archaeological Resources. Research at the Massachusetts and Rhode Island SHPO offices has identified literally hundreds of prehistoric and historic archaeological sites along the Blackstone River and vicinity in both states. Site files have not been reviewed to determine the extent or condition of resources present. This would be accomplished during the Feasibility as alternatives are more clearly defined. It should be noted that this database includes only those sites currently documented. Many other undocumented or yet-to-be-discovered sites may be located throughout the study area. In fact, the Blackstone River and vicinity may be characterized as having a high potential for prehistoric resources relating to Native American occupation of the area, and for historic archaeological resources relating to the initial settlement, industrial development and later settlement of the Blackstone Valley. Areas of high urban development and disturbance would probably have a lower sensitivity for archaeological resources than those of more isolated and less developed rural areas. In most cases, an intensive level archaeological survey of selected study locations may be required prior to construction. This will be determined during the feasibility phase of the study.

e. Sensitivity Potential for Undocumented Cultural Resources. The potential for undocumented cultural resources within selected project locations will be ascertained on a case-by-case basis as discussed above. Selection of alternatives could impact the degree to which archeological resources are affected. Any alternative requiring construction is likely to result in a requirement for archaeological surveys. Archaeological potential will be evaluated for each separate alternative at each study location. Specific project descriptions at each study area would need to be produced in order for a proper cultural resources assessment to be performed. This should be accomplished as soon as possible in the planning stage. All alternatives will be carefully screened and evaluated as part of the Section 106 process by both the Massachusetts and Rhode Island SHPOs, the Blackstone River Valley National Heritage Corridor Commission, the National Park Service, local governments, and any other interested parties including the general public and native american tribal entities.

Cultural resources of all types have been identified at all of the study locations and will be evaluated as part of the feasibility study assessment. During the feasibility phase, a detailed assessment of cultural resource alternatives and impacts would be performed including the preparation of specific project alternatives and design plans and specifications suitable for review, prior to the implementation of any project in the Blackstone River Reconnaissance study area.

2.5 Hazardous and Toxic Waste

There are dozens of hazardous waste sites including landfills, mills that have released contaminants, automobile junkyards, etc. in the basin. Many are along the mainstem river. There are a limited number of Federal Superfund sites in the basin. The remainder of the classified hazardous waste sites are under state jurisdiction. The regulatory agencies do not classify sites by river basin, therefore it is difficult to quickly assess which sites are relevant, and which are not to this study. The location and significance of these sites to projects will be determined during the feasibility study.

III. PROBLEMS AND NEEDS

3.1 Overview

Over the last several centuries development has resulted in significant loss of fish and wildlife habitat throughout the Blackstone River watershed. Prior to European colonization the watershed was largely forested. Virtually all the pre-colonial forest land was cleared by the mid- 1800's, mostly for agriculture. Since then, much land has either reverted back to forest or has been developed. Construction of residential, commercial, and industrial structures, impoundments, parking lots, roads and other infrastructure has destroyed thousands of acres of terrestrial, wetland, and riverine habitat.

In addition to habitat loss, human activities have degraded remaining aquatic, wetland, and riparian habitat in a variety of ways. Development has led to deposition of millions of cubic yards of sediment into rivers and streams, much of which has accumulated within impoundments. Thousands of tons of heavy metals and other contaminants have been released into streams and rivers, contaminating sediment and degrading benthic quality in many of the major impoundments. Sedimentation and nutrients released from wastewater treatment plants, non-point sources, and failed septic systems have resulted in eutrophication of lakes and impoundments and degradation of aquatic instream habitat. Loss of riparian vegetation, construction of impoundments, and impacts of development on baseflow have warmed streams, destroying cold water fisheries. Dams have blocked passage of anadromous fish to upstream spawning grounds. Hydropower operations are responsible for the dewatering of riverine habitat via bypass reaches and when water levels are drawn to below the spillway crests, and rapidly fluctuating streamflows that exacerbate streambank erosion. Human introduction of invasive exotic plants such as purple loosestrife have impacted native plant communities and degraded wildlife habitat.

For purposes of discussion, the problems identified in the Blackstone River Watershed Reconnaissance Investigation are categorized as follows:

1. Loss and degradation of wetland habitat;
2. Loss and degradation of riparian habitat;
3. Loss of anadromous fisheries;

4. Loss and degradation of lake and pond habitat;
5. Loss and degradation of river/stream habitat;
6. Degraded water and sediment quality.

It is recognized that the categories listed above are broad, and that some problems impact multiple categories. An example of this would be sediments and their resuspension. Sediments are deposited in ponds, wetlands and rivers, thereby degrading the associated habitat, but contribute additional damage when they become resuspended in the water column. Nevertheless, it is convenient to describe the problems by these broad categorizations. The problems are described in more detail in the following sections.

3.2 Loss and Degradation of Wetland Habitat

The USFWS estimates that development has destroyed 28 to 37 percent of colonial era wetland habitat in Massachusetts and Rhode Island. Although precise data is lacking for the Blackstone River basin, the basin is heavily developed and losses are likely to be similar to or greater than statewide estimates. Remaining wetlands are roughly 70 percent of that present in the late 1700's. The remaining wetland habitat has been lost due to filling and development, and for additional reasons described below. The extent of wetland loss likely varies with habitat type. Forested and scrub-shrub wetland is probably most heavily impacted. Because numerous impoundments have been constructed, the basin likely has significantly *more* open water habitat and less free-flowing riverine habitat today than in colonial times.

Over the decades, sediment has filled in many impoundments, resulting in a change in habitat from that of open water to that of wetlands/marsh providing important waterfowl habitat. With many dams having been poorly maintained, owners fearful of liability, or unwilling to incur the significant costs of dam maintenance, have drained the impoundments, removed the dams, or simply waited for the dams to fail. Failure of one or more dams is likely to result in the further loss of wetlands, including those behind the failed dam and those farther downstream. The destruction of these wetlands has been identified as significant on a watershed scale.

The habitat value of many wetlands in the basin has been degraded by invasive plants such as purple loosestrife (*Lythrum salicaria*), reed (*Phragmites australis*), and European buckthorn (*Rhamnus frangula*) . Loosestrife and *Phragmites* occur must commonly in emergent wetlands. Buckthorn occurs in scrub-shrub wetlands, and in the understory of forested wetlands (as well as in uplands). Purple loosestrife was probably introduced into the basin from Europe sometime in the 1880's and is now ubiquitous. It tends to crowd out native vegetation, reducing plant community diversity, and degrading wildlife habitat value. Wildlife habitat value suffers since loosestrife has low food value and provides inferior cover and nesting habitat. *Phragmites* occurs throughout the basin. Although native to North America, a common variety in eastern Massachusetts can be very invasive, forming essentially monotypic (single species) stands with little wildlife habitat value. Several large stands are present in the basin and many wetlands contain small stands that appear to be spreading. Buckthorn is a shrub that frequently occurs in forested and scrub shrub wetlands and riparian habitat. Like loosestrife and *Phragmites*, it can crowd out native vegetation, reducing plant community diversity. None of these species offer much food value for native wildlife. Replacement of these plants with a more diverse plant community would enhance wildlife habitat value.

The habitat quality of many remaining wetlands has been indirectly impacted by development in adjacent upland areas. Flow restrictions caused by road beds or other structures has altered wetland hydrology and plant communities in many locations. Numerous forested wetlands have been flooded by road beds that restrict normal drainage patterns and raise groundwater levels. A few wetlands in the Blackstone River basin have been drained by ditches for conversion of land to agricultural use or for land development purposes. This drainage is sometimes done in conjunction with channelization of streams and rivers.

3.3 Loss and Degradation of Riparian Habitat

As is the case for wetlands, riparian habitat (riverbank and floodplain) in the Blackstone River basin has been severely impacted by centuries of development. Along much of the Blackstone River and lower reaches of major tributaries, riparian buffers are less than 200 feet wide and, in urbanized areas, often less than 50 feet wide. Particularly heavily developed areas include the communities of Worcester and Blackstone in Massachusetts and Woonsocket in Rhode Island.

Riparian buffers of at least 50 to 100 feet wide are needed to protect water quality and at least 200 to 300 feet wide to provide adequate wildlife habitat and a travel corridor. Large blocks of riparian habitat greatly benefit fish and wildlife populations by providing cover, foraging habitat, and nesting habitat for many resident and migratory wildlife species, especially interior orientated species, resident species with large home ranges, and species which require a variety of habitat types. Benefitting species include reptiles (e.g. spotted turtle and wood turtle), birds which require wide buffer strips (e.g. scarlet tanager and wood thrush), raptors (e.g. red shouldered hawk and great blue heron), and mammals (fisher). Forested riparian habitat is usually preferable to more open grassland habitat, although both have value. The loss of forested riparian habitat has resulted in a loss of aquatic food chain support (leaf fall) and input of large woody debris and, increased water temperature due to loss of shade in small streams (e.g. Peters Brook and the Mill River). The loss of riparian buffers has also resulted in a loss of greenways for recreation, and a reduction in aesthetic values.

Development has also fragmented riparian habitat into isolated patches too small to support populations of many wildlife species. Broad zones of undeveloped riparian habitat remain mostly in protected areas along the Blackstone River (e.g. Rice City Pond) and the upper reaches of the Mumford River, West River, and other tributaries. Many of these areas are under pressure from residential development.

Further degradation of the riparian habitat occurs when riverbanks are stripped of natural vegetation and riprapped for erosion control. Although riprap stabilizes banks, which along the Blackstone are generally contaminated with metals and oils, it is not environmentally sensitive, and destroys vegetation as it is placed and later maintained. The Corps of Engineers has placed riprap at three Local Protection Projects (the Blackstone, Woonsocket, and Lower Woonsocket LPPs) constructed to provide protection to flood prone areas. All three LPPs are in highly urbanized areas with very limited adjacent riparian habitat. Based on site visits and interviews with resource agency personnel, streambank erosion, in general, is not a significant basinwide problem in the Blackstone River watershed. It is prevalent only downstream of the mainstem river's hydropower plants and along the banks of some of the Blackstone River's impoundments.

3.4 Loss of Anadromous Fisheries

The Blackstone River and its tributaries historically supported spawning runs of anadromous fish species including American shad, alewife, blueback herring, and Atlantic salmon. Unfortunately, the extensive construction of dams for water power in the late 1700's and 1800's prevented these migratory fish from returning to the river basin's historical spawning and nursery habitat areas and consequently these fish runs were completely eliminated.

The continued loss of anadromous fisheries is caused primarily by dams. Dams block the upstream migration of anadromous fish to upstream spawning areas and the downstream return to the ocean. Numerous dams exist on the Blackstone River and its tributaries. Currently, there are 17 dams on the river, all of which are between 7 and 25 feet high, with the exception of the 40 feet high Thundermist Dam in Woonsocket.

In addition to the blockage of migrations by dams, acid deposition and subsequent stream acidification may be a major problem in the decline and/or restoration of many anadromous fish. As reported in the Chesapeake Bay Program (1989), low pH and high dissolved aluminum often occurs in many Eastern shore streams following heavy spring rains. Other potential problems include the adequacy of streamflows during the critical life-cycle periods of August and the spring upstream migration period, and water and sediment quality.

3.5 Loss and Degradation of Lake and Pond Habitat

Nearly half of the lakes and impoundments within the Blackstone basin are classified as eutrophic or hypereutrophic. Eutrophic lakes are characterized by high nutrient levels, excessive algal and aquatic macrophyte production, and wide diurnal variation in dissolved oxygen levels which degrade fish and macrophyte communities. Most of the rest are mesotrophic. Mesotrophic lakes are those with moderate phosphorus levels and productivity. In most freshwater systems, phosphorus is the primary nutrient of concern. Phosphorus sources include both non-point runoff and point sources, such as wastewater treatment plants. Internal recycling of phosphorus is variable, but believed very important in some of the Blackstone's eutrophic impoundments.

Many eutrophic lakes and reservoirs in the Blackstone River have serious aquatic weed problems. Eurasian water milfoil is the most common problem species. Heavy growth can impair recreation use and cause very low dissolved oxygen levels as plants decompose. Japanese knotweed (*Polygonum aspidatum*) is widely distributed throughout the basin, particularly in disturbed areas, especially along riverbanks and in other wet areas. Both species tend to crowd out other plants. Neither of these species have much food value for native wildlife.

Many impoundments in the Blackstone River and heavily developed tributary streams are very shallow because of sedimentation. Several of the larger impoundments contain hundreds of thousands of cubic yards of sediment. In more extreme cases (e.g. the Singing Dam impoundment, Fisherville Pond, and Rice City Pond), much of the original open water habitat has been lost to sedimentation and remaining open water is very shallow. Shallow water depth can adversely affect fish and wildlife habitat value, cause excessive growth of emergent and aquatic vegetation, and pose recreational problems. High levels of contaminants in sediment in many impoundments probably degrades benthic invertebrate and fish communities.

Habitat provided by some Blackstone River impoundments is at risk due to deteriorating dams. Large impoundments most at risk are Fisherville Pond in Grafton and Lackey Pond in Northbridge and Uxbridge, MA. The Lackey Pond dam is scheduled to be repaired, but the condition of Fisherville Dam remains a problem. The failure of Fisherville Dam would result in the loss of numerous acres of open water (as well as its wetland habitat, see above), as would the failure of Lackey Pond.

3.6 Loss and Degradation of Riverine/Stream Habitat

Historically, portions of the mainstem Blackstone River and significant tributaries supported significant coldwater fisheries such as resident trout and Atlantic salmon (during the two-year freshwater portion of their life cycle). However, the construction of numerous dams throughout the basin changed significant lengths of river and stream reaches from free-flowing systems to relatively still water (sluggish) systems behind the dams. Increased detention times in the impoundments has resulted in an overall increase in ambient water temperatures. Ambient water temperature is further elevated by spillage over the spillways of each dam, particularly during the warm summer months. The lack of riparian cover has also contributed to elevated water temperatures. As a result, warmwater fisheries have replaced historical coldwater fisheries in significant portions of the mainstem Blackstone River and the major tributaries within the basin. Where groundwater recharges surface water flows, loss of recharge from impervious surfaces within the riverfront area may also increase water temperatures by lowering summer base flows. In some cases, summer stream flows are maintained almost exclusively from groundwater recharge. Coldwater fisheries still exist in the upper reaches of the basin where ambient temperatures are conducive to their survival.

With a few hundred dams remaining in the basin, and the "average" dam impounding several hundred feet of stream habitat, many miles of former free-flowing stream habitat has been lost. Natural free-flowing stream habitats have also been lost due to stream channelization. Corps of Engineers LPPs in Blackstone and Woonsocket, Rhode Island have damaged riverine habitat due to dredging and straightening of channels in the (flood) protected reaches. Another cause of riverine habitat loss is the covering of streams by putting them in culverts.

There has been documentation (RIDEM and others) of sometimes drastic non-natural river level fluctuations in the river, that are likely caused by the river's seven hydropower facilities. These fluctuations occur despite the fact that all of the hydropower facilities are required by FERC to be run-of-river. The fluctuations could be due to the cycling of headponds to maximize power production, the sudden start-up (which would flush downstream sediments) and shut-down of the turbines, turbines with non-variable speeds, or the lowering of ponds for trash rack cleaning. The fluctuations significantly impact aquatic and riparian habitat by stranding fish eggs, juvenile fish, and other aquatic life, reducing waterfowl production, and creating other than ideal water depths for aquatic life. Additionally, the fluctuations cause slumping of the banks and the erosion and resuspension of sediments. Hydropower facilities are also responsible for the dewatering of bypass reaches. In one case (the Tupperware Hydropower Facility), the dewatered reach is one mile long.

Suspended sediments eventually settle out in slow moving riverine habitat (or impoundment habitat). These sediments affect benthic macroinvertebrates (bottom-dwelling organisms) most often by burying and smothering them. Sediment scouring action may also impact benthic macroinvertebrates. Sediments impair reproduction in some fish species. Trout, which spawn on beds of gravel in fast-moving, oxygen-rich streams, are especially susceptible to sedimentation. The growth and productivity of these fish are also influenced by the reduction of the available food supply of invertebrate species, caused by a sediment-laden river bottom. Aquatic insects preferred by trout (caddis fly, stonefly, mayfly, and blackfly) are among the species most likely to be affected by sedimentation, thus reducing the food supply.

3.7 Degraded Water and Sediment Quality

The problems of degraded water quality and degraded sediment quality appear, at first glance, to be separate, yet they are inextricably linked. Sediment resuspension has been identified by the Blackstone River Initiative as a major problem impacting water quality. Sediment resuspension occurs when water velocities increase during wet weather events, or because of hydropower-caused streamflow fluctuations. The resuspended sediments cause problems to water quality by its physical presence (turbidity) and by the contaminants bound to the sediments. The problems of degraded water and sediment quality are therefore discussed together.

Water quality has improved significantly over time mostly due to the tightening of NPDES permits of municipal and industrial dischargers. However, water quality parameters are still believed to play a significant role in the degraded health of the Blackstone's aquatic ecosystem. These parameters include low dissolved oxygen and high water temperature (previously discussed in Section 3.6), turbidity, and heavy metal concentrations. Low dissolved oxygen is primarily related to excessive nutrients. High water temperatures are caused by dams and a lack of riparian cover. High turbidity and elevated metals concentrations are caused by point and non-point sources, including the resuspension of sediments in the system. Sediments probably become resuspended more often at higher water velocities, with greater areas of the overbanks affected. In general, movement of sediment begins at water velocities of about 2 feet per second in loose, non-cohesive sediment. When water velocities exceed 3.5 feet per second, much of the sediment, including silty clays, is resuspended. Banks and river bottom sediments are also scoured by hydropower operations.

Turbidity, caused by suspended sediments, decreases light penetration in the water column, changing the structure and function of the aquatic community. Sight-feeding fish such as trout and forage fish (e.g. shiners) cannot locate their prey which affects the predator-prey relationships. Poor light transmission, combined with elevated levels of nutrients, can also supress the growth of submerged aquatic vegetation or even eliminate plant species vital to the food chain. Additionally, the suspended inorganic particles reduce fish gill efficiency and, can suffocate fish, at high enough levels. Recent limited studies have shown that the contaminants associated with suspended sediments may not have a significant affect on water quality and, subsequently, the resident fisheries. Results of these studies indicate that the contaminants may be "binding" to the sediments, both settled and suspended, in a variety of ways, making them biologically unavailable.

Water quality criteria for metals, both chronic and acute, are violated for much of the length of the Blackstone River and its tributaries with both point and non-point sources contributing to the problem. Because water quality standards are biologically-based, they imply a significant impairment of aquatic resources. The dominance of the warmwater fish population in the major impoundments by pollution-tolerant species (white sucker, golden shiner and carp) confirms that the Blackstone River system is degraded. However, other evidence indicates that the problem may not be as severe as would be expected. Testing by the Blackstone River Initiative indicated that during dry weather conditions, water toxicity due to metals was unexpectedly low, despite high concentrations of metals. (Wet weather conditions produced toxic water quality, as expected). A limited "weight-of-evidence" analysis of existing data at Fisherville Pond performed for this Reconnaissance Investigation also indicates that, despite its impaired status, water quality may not pose a significant observable direct risk to the fish community. However, the macroinvertebrate community, which functions as an important food source for the aquatic food web, is directly adversely impacted, therefore there are indirect impacts to the fish community. Reasons for the unexpected lack of dry weather toxicity are unclear, but could be due to some type of "binding" that makes contaminants biologically unavailable, or other reasons. Metals criteria violations, although important, may not be as significant as other water quality parameters.

Years of uncontrolled industrial discharges and non-point sources have contaminated sediments in Blackstone River basin impoundments with heavy metals, petroleum hydrocarbons, PCB's, PAHs, and pesticides (see Section 2.1.12.1 and Appendix F). Contaminant levels appear highest in impoundments on the Blackstone River and the industrialized reaches of major tributaries such as the Mumford River. The most highly contaminated sites identified to date include Singing Pond, Fisherville Pond, the former Rockdale Impoundment, Rice City Pond, and Manville Dam on the Blackstone River and Gilboa Pond on the Mumford River.

Several lines of evidence suggest that sediment contamination in Blackstone River impoundments poses a significant risk to benthic organisms. Concentrations of lead, copper, zinc, chromium, and other metals are generally far greater than literature-based sediment quality criteria thought to be protective of aquatic life. Available whole sediment and pore water sediment toxicity data suggests that sediments in many Blackstone River impoundments are toxic to benthic invertebrates. Actual data on benthic invertebrate communities in Blackstone River impoundments is limited to a few samples taken at Fisherville Pond for this study. The results suggest that the Fisherville benthic invertebrate community is not highly degraded. Additional studies are needed to resolve the apparent conflict between sediment chemistry and toxicity data, and benthic invertebrate data from Fisherville. Benthic invertebrate data is also needed from other impoundments to help assess habitat quality. If benthic communities are found to be degraded, studies would be needed to identify toxicants and establish remediation goals.

Sediment contamination may also pose a direct or indirect risk to fish, birds, and mammals through direct toxicity or sublethal effects on growth and reproduction. A preliminary risk assessment conducted for this study found that sediment contamination at Fisherville, one of the more highly contaminated impoundments, is not likely to pose a significant adverse risk to herbivorous waterfowl such as mallard, fish eating birds such as the great blue heron, or omnivorous wildlife such as muskrat. Additional studies are needed at Fisherville and other impoundments to confirm this conclusion.

Contaminated sediment may pose some risks to human health, either through direct contact (dermal exposure) accidental ingestion of sediment, or consumption of fish with elevated levels of contaminants. At Fisherville, possible significant risks associated with incidental ingestion and dermal contact with the PAH benzo(a)pyrene and chromium were identified. PCB and lead levels in fish from the pond were also identified as potentially significant risks. Risks due to elevated PCB levels in fish also exist at Rice City Pond, the Riverdale Impoundment, and Tupperware Dam. Additional testing of sediment and fish for PCBs is needed, especially in impoundments on heavily industrialized tributary streams.

Risk Assessment

Human health and ecological risk assessment is defined as a process that evaluates the likelihood that adverse effects to human health or the ecological environment may occur as a result of exposure to one or more contaminants. The basic elements in risk assessment include the processes of hazard identification, dose-response assessment, exposure assessment, and risk characterization. Human health risk assessment has been used by the USEPA and state regulatory agencies since the early 1980's to assess (i.e. quantify) the degree of threat posed by hazardous waste sites to humans, and is the primary means of determining cleanup levels. More recently, there has been a trend by the regulatory agencies to also quantify the risks to the ecological environment through ecological risk assessment.

Hazard identification is the process of showing causality, that is, "does a chemical cause cancer (a carcinogen) or induce some other adverse effect such as reproductive dysfunction or birth defects (a teratogen)?". The answer to this is either yes or no, although there are often uncertainties.

Dose response assessment determines the magnitude of the toxic response. This is usually accomplished experimentally, in the laboratory. Distinctions are made between carcinogens and non-carcinogens.

Exposure assessment determines the magnitude, frequency, and duration of exposure of the chemicals to the human or ecological "target receptor". Various assumptions are made about how the receptor would be exposed (and for how long and how much), and how the receptor would ingest, inhale, or touch the chemical.

Risk characterization integrates the findings of dose response and the assumptions of exposure to produce, at least for human risk assessment, a numerical estimate of the risk from the chemical(s).

After the risks have been assessed, the risks must be managed, typically by controlling the potential for exposure of the chemical(s) to the receptors. Typically, costs, feasibility and political issues surface that complicate the balancing of risks. Because risk assessment involves so much uncertainty, and because the costs of reducing the risks are often large, the assumptions used in the risk analysis are often criticized. Risk assessment is, however, one of the only tools available for quantifying environmental risks.

Source of this information: U.S. Army Engineer Waterways Experiment Station, "Environmental Effects of Dredging Technical Notes", EEDP-06-15, December 1991.

IV. OBJECTIVES AND FORMULATION

During the reconnaissance phase, planning efforts have been primarily directed toward formulating feasible solutions to environmental problems in the Blackstone River watershed and identifying the locations for their implementation. The Corps has the authority to implement projects primarily related to the improvement of fish and wildlife habitat. Although the primary purpose of a reconnaissance report is to determine whether further Corps studies are warranted, the study investigated all important ecological issues within the study area to develop an overall plan to restore the watershed. Restoration projects eligible for Corps implementation will be identified, however, it is important to recognize that portions of the recommended watershed plan will require implementation by other Federal, state, and local agencies.

4.1 Federal Objectives

The traditional Federal objective in water and related land resources project planning is to contribute to National Economic Development (NED) in order to alleviate problems and/or realize opportunities related to water and related land resources, consistent with protecting the Nation's environment. This objective was established by the U.S. Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G) dated March 10, 1983. Contributions to NED increase the net value of the national output of goods and services expressed in monetary units (i.e. benefits exceed costs).

Water and related resources plans are formulated to alleviate problems and to take advantage of opportunities that contribute to the NED objective. The intent of the focus on NED is to justify to the Federal Government that it is funding fiscally responsible projects. The process typically involves formulation of several alternatives for the solution of the water resources problems. The alternative that maximizes the net contribution (the amount by which the annual benefits exceeds annual costs) is defined as the NED plan.

The Corps Civil Works budget guidance currently assigns priority to the restoration of ecosystems and associated ecological resources. Therefore, consistent with the analytical framework established by the P&G, plans to address ecosystem restoration should be formulated, and measures for restoring ecological resources may be recommended. However, unlike traditional civil works water resources projects, watershed restoration plans and proposed ecosystem restoration projects do not have to contribute to national economic development. Environmental benefits are not assigned a dollar value against which project cost is compared. Restoration measures should be evaluated on the basis of non-monetary outputs compatible with the P&G selection criteria. Proposed projects, however, must be cost effective, i.e. environmental outputs such as increased habitat acreage at a site must be obtained at a lower cost than that of alternative proposals at the same site (with all other factors being the same). Proposed projects must also be in line with current budgetary guidance. Opportunities to also contribute to NED should be considered by planners when formulating plans for ecosystem restoration. Restoration measures which accomplish water quality improvement, habitat restoration, recreation, flood damage reduction, etc., are most likely to possess both NED and environmental quality benefits.

For small projects, cost effectiveness is generally assessed based on professional judgment. For complex projects, Corps planners conduct cost effectiveness and incremental cost analyses. The analyses are done to identify those plans which are most cost effective in providing environmental benefits, to eliminate inefficient plans, and to help determine if plans which provide additional (incremental) environmental outputs are cost effective. The analysis aids decision-making by ensuring that the least cost solution is identified for all levels of environmental outputs. The selected plan is generally the alternative which provides a reasonable level of environmental benefits at the lowest per unit cost. Corps participation in environmental restoration projects is not limited to locations of prior Corps activities, however, such projects typically receive higher budgetary priority.

The Federal objective of ecosystem restoration is to restore fish and wildlife habitat that is recognized as significant by institutional, public, and technical communities. The Corps area of involvement in achieving this objective is primarily through the manipulation of the hydrologic regime and/or the underlying substrate, areas which the Corps has significant experience. Although net NED benefits do not have to be exhibited, it is recognized that restoration projects which accomplish water quality improvement, habitat restoration, and recreation goals most likely will possess both NED and environmental quality benefits. Besides identifying if further detailed study is warranted, the Blackstone River watershed reconnaissance study identifies a plan of action and solutions to restore the ecological environment of the Blackstone watershed.

The Blackstone River watershed's fish and wildlife resources increasingly have been recognized as important. The valley's Congressional designation in 1986 as a National Heritage Corridor elevates the national importance of these resources. The efforts of several Federal, state and local agencies are now focused upon the restoration of the environmental resources of the Blackstone. The restoration will likely lead to improvement of Narragansett Bay, an important national estuary.

4.2 Planning Objectives and Constraints

Planning objectives and constraints are expressions of public and professional concerns about the use of water and related-land resources in a particular study area. These planning objectives and constraints result from the analyses of existing and future conditions within the context of the physical, environmental, economic, and social characteristics of the study area. They are used to guide the formulation of alternatives and to evaluate the effectiveness of these alternatives. The primary objective of the Blackstone River Watershed Reconnaissance Study is:

To develop a water resources plan that will improve fish and wildlife habitat in the Blackstone River watershed using a holistic approach in assessing and analyzing resources while preserving its historic character.

The primary objective can be broken up into three more specific sub-objectives. These sub-objectives are as follows:

1. Document the historic and current conditions of the Blackstone River watershed.

2. Propose actions to restore environmental status while maintaining the historic character of the watershed.

3. Identify potential actions which the Corps of Engineers could perform to accomplish the goal of the restoration plan.

4.3 The "Without Project" Condition

The future without project condition will include some improvements in water quality due to more restrictive EPA mandated point source discharge requirements. These actions will reduce BOD, suspended sediments, coliform and nutrient levels. The river will continue to experience elevated levels of metals and other contaminants due to non-point source runoff and the resuspension of sediments in the river. This problem could potentially be exacerbated due to a major release of contaminated sediments from an impoundment due to the failure of one of the several deteriorating dams on the river. The presence of elevated levels of metals and other contaminants will continue to result in degraded resident fisheries, waterfowl habitat, and benthic macroinvertebrates. The continued deposition of sediment will degrade existing wetlands and habitat areas. Habitat areas, particularly for waterfowl, will continue to be lost due to the draining of impoundments to minimize the risk of dam failures.

The future without project condition will also result in the continued lack of anadromous fish passage in the basin. While current Federal and state agencies' efforts with FERC will probably result in the discontinuation of any hydropower induced flow fluctuations, they are unlikely to force construction of passage facilities.

V. WATERSHED PLAN

5.1 Watershed Plan Development and Plan Formulation

This reconnaissance investigation relied on an ecosystem-based approach to identify the Blackstone River basin's problems, needs, and opportunities, and to select prototype projects to address the environmental deficiencies throughout the watershed. An ecosystem-based approach assesses the condition of existing ecosystems (or watersheds) and determines the feasibility of restoring degraded ecosystem structures, functions, and dynamic processes to a less degraded state. Emphasis is placed on maintenance and restoration of a variety of ecosystem functions, rather than attainment of narrowly focused objectives. Ecosystem restoration planning strives to protect or improve biodiversity and focuses on the long-term sustainability of all resources in the landscape, rather than specific species or habitat types. The ecosystem approach also facilitates evaluation of the cumulative effects of restoration efforts within a defined area ecosystem.

The ecosystem restoration approach can be applied on a variety of landscape scales ranging (in this study) from an entire basin to a small subbasin of tributary streams. Focusing on smaller watersheds within a large river basin is often preferred because it allows a planning team to better correlate the ecological resources to the hydrologic system and land use. A subwatershed provides a convenient hydrogeographic boundary in which resources can be more accurately described, have its needs evaluated, and the impacts of restoration efforts predicted and monitored. Because of funding and time constraints, it was not possible to conduct detailed subwatershed level analysis of the entire 475 square mile Blackstone River basin. The study determined the overall problems and needs of the entire watershed, but then focused plan formulation on the main stem of the Blackstone River, the recipient of the worst environmental abuse in the watershed. Additional effort was also directed at the 58 square mile Mumford River sub-watershed, chosen because it had problems believed representative of the Blackstone's sub-watersheds.

The evaluations conducted as part of this reconnaissance investigation identified significant ecological degradation in the mainstem Blackstone River and in many of its tributaries. The principal causes of the degradation in the watershed were found to be the disruption of wetlands and other habitat areas within the watershed, the historic discharge of industrial and domestic contaminants into the river, and the construction of dams which alter the character of the river. The reconnaissance study identified the need to implement restoration/improvement projects to improve the overall ecological health of the river. Due to the funding constraints inherent with a Reconnaissance study, ***the scope of this effort was limited to developing preliminary designs and cost estimates for prototype projects which demonstrate opportunities for the Corps to improve the health of the ecosystem.***

This report reflects the philosophy and policy of the draft Engineering Circular (EC) 1105-2-206, "Ecosystem Restoration Planning in the Civil Works Program". This and other applicable ecosystem restoration documents guided project selection. Corps activities in ecosystem restoration concentrate on engineering solutions to water and related land resources problems. The principal focus is on those ecological resources and processes, that are directly associated with, or directly dependent upon, the hydrologic regime of the ecosystem and watershed. Not all ecosystem restoration opportunities are appropriate for Corps involvement. Those restoration opportunities that involve modification of hydrology or substrate are likely to be most appropriate for Corps initiatives. Such activities are most likely to involve wetland, riparian, or aquatic ecosystems. The Corps generally does not conduct ecosystem restoration activities on upland, terrestrial sites that are not closely linked to water and related land resources. Corps involvement in improving water quality focuses on manipulation of hydrology to improve water quality parameters, rather than pollution abatement, which is under the purview of state and other Federal agencies.

It is desirable to propose environmental restoration measures able to address multiple ecosystem restoration objectives, establish diverse and self-sustaining natural communities (consider game and non-game species), provide long-term benefits with minimal long-term maintenance, maximize environmental benefits and minimize adverse impacts, be supported by the public, be consistent with historic preservation goals, and be cost effective. Projects formulated to achieve several of these objectives are more likely to receive regulatory agency approval.

The key to successful watershed restoration is good planning. Overall ecosystem restoration goals should be established in light of site specific opportunities and constraints. In general it will be desirable to establish a variety of habitat types to maximize for fish and wildlife value. Opportunities may exist at an old gravel pit, for example, to establish a mosaic of emergent wetland, open water, forest and grassland habitat. Environmental restoration work typically involves many of the following tasks: restoration of appropriate site hydrology, removal of fill or waste material, removal of pavement and buildings, site grading, soil restoration, planting of vegetation, post construction monitoring, and long-term site management. In instances where soils and vegetation remain, a site can simply be protected from future development, cleaned up, and managed over a period of decades to allow natural communities to develop. Highly disturbed sites will often require substantial earth work, soil improvement, and planting vegetation to "jump-start" the restoration process.

5.2 Project Identification Process

After the problems of the watershed are identified, general (non site-specific) solutions to these problems are described and a number of site-specific prototype projects are formulated. The general philosophy of the Corps Reconnaissance Investigation team was that it was appropriate to study both "prototype projects" as well as generic solutions with potential widespread applicability. Prototype projects were selected by the team and others in order to demonstrate the types of projects that the Army Corps of Engineers could perform to improve fish and wildlife habitat in the Blackstone River watershed at these and other locations. Presentation of prototype project configurations and costs in this report therefore should not be construed as a Corps prioritization or preselection of locations requiring environmental improvement, nor even the actions that should be implemented at those sites since *the purpose of the Reconnaissance Investigation in project formulation is mainly to identify the types and costs of actions that could be undertaken by the Corps.* It is during the feasibility investigation that sites and specific restoration activities are selected.

Prototype projects selected for further description and analysis were formulated with the objective of environmental improvement consistent with historic preservation. Environmental improvement is sometimes at odds with historic preservation. An example of this concerns the lack of fish passage up and down the river. The most obvious solution to this problem is to remove the blocking dams. However, many of these dams have historic significance, being either listed, or eligible for listing on the National Register of Historic Places. Congress has designated the Blackstone River Valley as a National Heritage Corridor precisely for the area's national significance and for the purpose of "preserving and interpreting historic and cultural lands, structures and waterways of the Valley for the educational and inspirational benefit of all" (Public Law 99-647, November 10, 1986).

It was felt that it would be desirable to propose projects in both ponded reaches and in free-flow river reaches on the mainstem river. The mainstem river was believed to be a good choice for focused efforts for a number of reasons. Its headwaters are located in the heavily industrialized city of Worcester; combined sewers and numerous wastewater treatment plants discharge to the river; and the heavily industrialized city of Woonsocket abuts the river. In addition, the mainstem river's steep gradient and greater hydropower opportunities resulted in more industry and associated industrial dumping of wastes into the river, resulting in widespread contamination of the river and its floodplain. Opportunities for restoration were therefore believed more prevalent on the mainstem. Also, with the Blackstone River as the centerpiece of the National Heritage Corridor, and flowing through both Massachusetts and Rhode Island, it was believed that restoration opportunities identified on the mainstem river were more likely to be appropriate for prototype purposes, and perhaps more likely to illustrate the type of actions that would be implemented.

Reconnaissance investigations are limited to readily available existing information and activities of short duration. Knowledge gained during the Army Corps of Engineers November 1994 "Blackstone River Restoration Study" was used to help guide overall study items and identify mainstem areas with environmental needs. Participants at a June 4, 1996 Reconnaissance Investigation kickoff meeting also nominated specific sites and actions at those sites, and suggested generic-type actions that should be investigated. The technical knowledge of the participants, and their familiarity with the Blackstone watershed, helped ensure that the sites and actions were appropriate and worthwhile.

Fisherville Pond, located in Grafton, Massachusetts, was selected as the focus of investigation of remedial measures appropriate for mainstem river impoundments. Fisherville Pond was selected because it was considered to have a representative slice of the watershed's problems (at least for the ponded segments) and because of its mainstem location where the most significant environmental degradation has occurred. Fisherville Pond had also been identified as one of the two top sources of sediment resuspension in the basin (the other being Rice City Pond in Uxbridge, MA) by the Blackstone River Initiative. Primary actions to be considered at Fisherville were to include rebuilding the dam and outlet works, restoration of appropriate water levels, and the dredging or capping of contaminated sediments. Other actions to be considered, if appropriate, would be raising or even removing the dam, diverting some or all of the flow around the pond, providing fish and/or canoe passage, restoring the Blackstone Canal and other historic features, etc. It was felt that what was learned at Fisherville would likely be applicable to other ponded locations, particularly those linked with past industrial development.

A significant effort was also proposed to determine the feasibility and cost of implementing fish passage facilities at the four most downstream dams on the Blackstone River in Pawtucket, Central Falls and Cumberland, Rhode Island in order that anadromous fish be restored to the Blackstone watershed. Other projects selected for prototype-level investigation included the restoration of a wetland at the former Lonsdale Drive-In site in Lincoln, Rhode Island, restoration of riparian habitat at the former Rockdale Pond site (Coz Chemical) in Northbridge, Massachusetts, the daylighting of Beaver Brook in Worcester, Massachusetts, and implementation of a sediment capture pond (Singing Pond) in Sutton, Massachusetts to protect environmental resources at downstream locations. Consideration was also to be given to the raising of a dam (using Rice City Pond in Uxbridge, Massachusetts as an example) to increase wetland/waterfowl habitat. Likewise, restoration of an abandoned gravel pit (using the Riverdale gravel pit in Northbridge, Massachusetts as an example) was considered to increase wetland/waterfowl habitat. Corps projects in Worcester and Blackstone, Massachusetts, and Woonsocket, Rhode Island were also investigated to determine their potential for environmental restoration measures.

Additional habitat restoration projects in the Blackstone basin were identified through coordination with local, state, and Federal agencies, and the interested public. However, identification of projects was not performed comprehensively. Requests for information were provided to about 100 persons, agencies, and organizations including the USFWS, MADFW, RIDEM, the NRCS, town conservation commissions, town planners, non-governmental environmental organizations, and the environmental consulting community. The request was also published in the news letter of the Association of Massachusetts Wetland Scientists and distributed at a meeting of the Rhode Island Restoration Team. The purpose of the questionnaire was primarily to obtain information on the extent of the problems, and to solicit solutions and the types of actions that were felt to be needed to address the problems. Sites nominated were primarily all on the mainstem Blackstone River. The information request and site report form are provided in Appendix B. Results from the approximately 50 survey respondents are summarized in Table 11. Sites nominated were mostly in the northern part of the basin. Most of the potential projects had the goal of wetland or riparian habitat restoration and typically involve removal of fill material, *Phragmites* control, and/or revegetation of disturbed areas or agricultural fields. Results of the survey were spotty and demonstrate the need for a systematic survey of habitat restoration opportunities throughout the entire basin.

Another way sites were identified was by a Corps examination of the Mumford River sub-basin (see Figure 4). A list of sites (see Table 12) in the Mumford River sub-basin was generated through use of Geographical Information Survey (GIS) mapping, aerial photography, field investigations, literature search, and discussions with resource agency personnel.

A November 19, 1996 meeting with a 15-person advisory committee, consisting of members of EPA, USGS, MADFW, RIDEM and the BRVNHCC, resulted in general concurrence with the Corps-proposed approach to studying the watershed, including the specific prototype projects to be examined, and the ideas to be considered at the prototype projects.

5.3 Environmental Restoration Measures

This section describes a variety of measures which could restore lost or degraded fish and wildlife habitat and other ecosystem functions in the Blackstone River watershed. These techniques were identified based on a review of the technical literature, discussions with state and Federal resources agencies, and the professional experience of the study team. All the proposed techniques have been successfully applied elsewhere. Many of these measures are integrated into prototype plans presented in Section 6.

The Blackstone River watershed's problems were identified and discussed in Section III (Problems and Needs). These problems are:

1. Loss and degradation of wetland habitat;
2. Loss and degradation of riparian habitat;
3. Loss of anadromous fisheries;
4. Loss and degradation of lake and pond habitat;
5. Loss and degradation of river/stream habitat;
6. Degraded water and sediment quality.

The following sections of the report describe the solutions to the six identified problems. Because of the close interactions of many of the above problems, the solutions formulated to address one of these problems may solve others as well. However, often the solution to one problem has negative impacts on another problem. It is proposed that the pros and cons of site-specific formulated solutions be evaluated in detail in the feasibility study.

Mumford River Sub-basin

A pilot study to identify habitat restoration projects in a representative sub-basin was conducted. The goal of the study was to further access the watersheds problems, identify potential Corps projects, and develop a database of environmental restoration projects which may be useful to other federal, state, and local agencies. The study also illustrates methods which could be applied throughout the entire Blackstone River watershed during the feasibility study.

The 58 square mile Mumford River sub-basin was considered representative of the watershed for the following reasons: it has numerous ponds, two wastewater treatment plants, several historic mills and villages (Whitinsville and Manchaug), and water quality problems associated with urban land use. The overall land use of the Mumford sub-basin is fairly representative of that of the larger Blackstone River watershed, although the Mumford may have a greater percentage of open space. In addition, the University of Massachusetts Cooperative Extension had done a study on the impacts of possible Mumford River basin "build-out" scenarios on water quality.

Habitat restoration opportunities were identified by contacting individuals familiar with the basin, review of existing information, and through field studies by Corps personnel. Individuals contacted include MADFW personnel and local conservation commissions. Corps studies involved review of existing reports, ACOE Regulatory Division files, USGS quadrangles, soils maps, and photointerpretaiton of 1:40,000 scale color infrared aerial photographs to identify candidate sites and follow-up field visits.

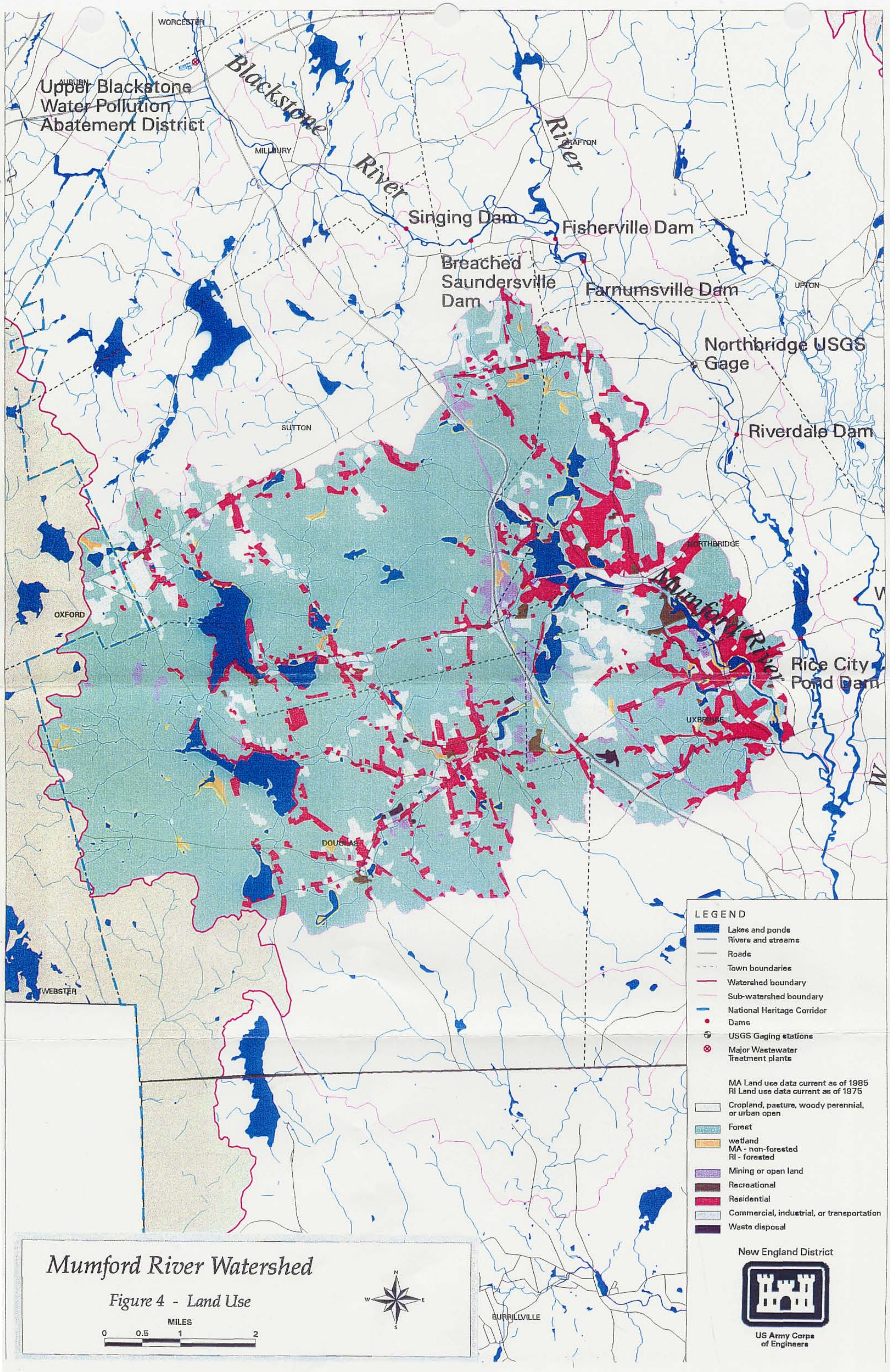
Approximately 20 potential restoration projects were identified (see Table 12). Relatively large scale projects which may be suitable for Corps involvement include restoration of a large abandoned gravel pit in Northbridge, the dredging of Whitin Pond in Uxbridge and Manchaug Pond in Manchaug. Many of the projects identified are small and perhaps best implemented on the state or local level.

Table 11: Environmental Restoration Opportunities Identified by other Agencies, Organizations, and Individuals.

Town	State	Locus	Associated Stream, River, Wetland, or Impoundment	Project Description
Wetland Restoration and Enhancement				
Cumberland	RI	South side of Rt. 114, just west of Wrentham Rd.	Unnamed wetland	Restore 4 acre drained wetland.
Grafton	MA	low area located south of Rt. 122 between Quinsigamond River and Hudson Ave.	Quinsigamond River	Construct wetland by expanding and deepening existing depression.
Grafton	MA	Isolated wetland north of Route 140 near Town DPW	Unnamed wetland	Eliminate heavy infestation of *Phragmites* from isolated 2 acre scrub-shrub wetland.
Grafton	MA	Southeast of intersection of Sibley St. and Route 140	Unnamed stream	Remove fill material encroaching upon emergent wetland and stream channel.
Grafton	MA	Route 140, behind Burger King	Unnamed wetland	Restore 2.5 acre emergent/scrub-shrub wetland degraded by fill material and *Phragmites*.
Grafton	MA	Soap Hill Road just west of Upton town line	Miscoe Brook Watershed	Remove ditches draining large forested upland/wetland area to restore wetland hydrology and reduce stormwater runoff.
Lincoln	RI	Marsh situated north of Washington Highway, South of Route 295, West of Lincoln Mall	Town Line Swamp	Eradicate large (ca. 15 acres) stand of *Phragmites* and improve construct potholes to improve habitat diversity.
Millville	MA	West of 146 one mile north of Chokalog Road	unnamed wetland	Construct ca. 2 acre of wetland by lowering existing grade.
Northbridge	MA	East of Uxbridge, Northbridge WWTP	Blackstone River	Create several acres of wetland habitat at flooded gravel pit with historic outlet (wooden culvert) to Blackstone Canal.
Shrewsbury	MA	Western end of pond near Old Mill Road.	Mill Pond	Restore shallow marsh habitat at western end of pond by removing fill (unpaved parking lot) and eradicating *Phragmites*.
Shrewsbury	MA	West of Route 70 near marsh Dr.	Newton Pond	Create wetlands, restore upland habitat at large (40+ acre) abandoned gravel pit.
Wrentham	MA	Field located west of Locust St. and South of Washington St.	unnamed stream draining into Jenks Reservoir	Convert old field to wetland by placing small check dams in drainage ditch and possibly by lowering grade. Ten acre site.
Wrentham	MA	East of intersection of Cumberland and West St.	Indian Brook	Lower grade in old-fields to expand existing wetlands at headwaters of brook.
Uxbridge	MA	Impoundment on Blackstone River north of Hartford Avenue.	Rice City Pond	Access need for Phragmites control and implement control program if warranted to preserve or enhance habitat quality.
Upton	MA	Route 140, behind Togi's garage	Unnamed wetland	Restore ca. 1 acre wetland by removing unused parking area. Metals from fill is leaching into adjacent wetland.
Streambank Stabilization				
Northbridge/Uxbridge	MA	Blackstone River between Riverdale and Rice City Pond.	Blackstone River	Stabilize eroding embankments composed of contaminated sediment deposited as a result of historic breaching of Riverdale Dam (2 mile reach).
Riparian Restoration				
Grafton	MA	Field along Quinseamond River on west site of Route 122 just upstream of Fisherville Pond	Quinsigamond River	Convert/restore 30 acre agricultural field to forested riparian habitat.
Grafton	MA	Open area along Route 122A south of abandoned Fisherville Mill building parking lot	Blackstone River and Canal	Restore 5 - 10 acres of riparian habitat in disturbed area located between Blackstone River and Blackstone Canal.
Grafton	MA	North of Depot Road adjacent to Blackstone River	Blackstone River	Restore riparian buffer in disturbed area adjacent to river.
Millbury	MA	Route 122A, behind Honey Farms	Blackstone River	Restore riparian buffer disturbed by cutting of large trees and erosion along 150 ft. of river.
Millbury	MA	West of Milbury St. near Worcester/ Milbury Line	Blackstone River	Restore forested buffer, remove linear upland berms placed in riparian wetland.
Millbury	MA	Railroad tracks west of Millbury St. near Worcester/ Millbury Line	Blackstone River	Plant trees to restore forested riparian buffer along 1000 ft. reach.
Millville	MA	Field west of Old Millville Road	Blackstone River	Restore riparian 4 acre of riparian habitat in agricultural field located near river. Wetland habitat could be constructed by lowering grade.
Northbridge/Uxbridge	MA	Church St. south to vicinity of Goat Hill	Blackstone River and Canal	Repair breaches in Blackstone Canal towpath along Blackstone River to rewater the canal and restore towpath for use as a hiking trail. Breaches occur along 1.5 mile reach of canal.
Northbridge	MA	Route 122, behind "Northbridge Auto" junkyard	Blackstone River	Restore 3+ acres of riparian wetland and upland habitat by removing fill material, autos, and other debris. Control or treat of contaminants and sediment from site into Blackstone River.
Worcester	MA	Blackstone River between Route 20 and Millbury St.	Blackstone River	Restore riparian habitat filled many years ago with railroad gravel, cinders, and other waste along ca. 500 ft. reach of river.
Wrentham	MA	Washington St., just south of Franklin St. Park	unnamed tributary of Miscoe Brook	Convert/restore 8 acre agricultural field to riparian wetland/upland habitat. Construct small check dams in stream to increase water depth in spring.

Table 11: Continued

Town	State	Locus	Associated Stream, River, or Pond	Project Description
Stormwater Treatment/Detention				
Attleboro/Lincoln	MA RI	Gravel Pits east of Happy Hollow Pond in South Attleboro	Millers River, Happy Hollow Pond	Divert flow from Millers River/Happy Hollow Pond through constructed wetland treatment system to improve water quality and provide wildlife habitat.
Auburn	MA	Auburn Mall Parking Lot (off Route 12)	Dark Brook	Construct wetland treatment system to treat runoff from mall parking lot.
Worcester	MA	Stream arising from storm drains at Margaret School on Chandler St.	Unnamed tributary of Tatnuck Brook	Construct wetland treatment system to treat runoff from small urban sub-watershed.
Worcester	MA	End of Dunkirk Ave off Massosit Rd.	Broad Meadow Brook	Construct wetland treatment/sediment detention ponds at two locations to reduce siltation impacts on in-stream habitat and nutrient levels.
In-stream Habitat Improvement				
Auburn	MA	Auburn Mall Parking Lot (off Route 12)	Dark Brook	Place eddy rocks to create riffle and pool complex.
Bellingham	MA	Corner of 126 and River Bend Road, West of 495	Beaver Brook	Place eddy rocks to create riffle and pool complex along 300 ft. reach.
Worcester	MA	Beaver Brook parkway, North of Routes 9/12	Beaver Brook	Place eddy rocks to create riffle and pool complex along 1200 ft. reach.
Worcester	MA	Freemont Street, south of Webster Square	Middle River	Place eddy rocks to create riffle and pool complex along 1800 ft. reach. Restore riparian buffer were possible.
Worcester	MA	End of Dunkirk Ave off Massosit Rd.	Broad Meadow Brook	Restore in-stream habitat within channelized 0.5 mile long reach of brook. Opportunities also exist to improve habitat by stormwater treatment, riparian restoration, and wetland creation.
Pond/Impoundment Restoration				
Mendon	MA	Pond immediately north of Northbridge St.	Rock Meadow Brook	Dredge eutrophic pond to improve habitat value and sediment capture efficiency.
Worcester	MA	Former pond on Tatnuck Brook south of Pleasant St. and north of Patch Reservoir	Former Smith Pond on Tatnuck Brook	Restore drained pond to enhance sediment capture efficiency and protect Coes Reservoir. [Impacts to nearby housing and wetlands need to be evaluated].
Worcester	MA	Pond on Tatnuck Brook, east of Mill Street, north of Coes Reservoir	Williams Mill Pond	Repair Williams Mill Pond spillway. Dredge pond to improve sediment capture efficiency and protect Coes Reservoir.
Worcester	MA	Pond on Tatnuck Brook south of Patch Reservoir	Patch Pond	Repair deteriorated spillways (2) to stabilize water levels; control bank erosion.
Worcester	MA	Pond on Tatnuck Brook down-stream of Coes Reservoir	Coes Mill Pond	Dredge pond to improve sediment capture and downstream habitat (Middle River)
Worcester	MA	Pond on Tatnuck Brook upstream of Pleasant St.	Cook's Pond	Control sedimentation from housing development at northwest end of pond. Possible dredging.



Mumford River Watershed
Figure 4 - Land Use
MILES
0 0.5 1 2
N
S
E
W
LEGEND
Lakes and ponds
Rivers and streams
Roads
Town boundaries
Watershed boundary
Sub-watershed boundary
National Heritage Corridor
Dams
USGS Gaging stations
Major Wastewater Treatment plants
MA Land use data current as of 1985
RI Land use data current as of 1975
Cropland, pasture, woody perennial, or urban open
Forest
wetland
MA - non-forested
RI - forested
Mining or open land
Recreational
Residential
Commercial, industrial, or transportation
Waste disposal
New England District
US Army Corps of Engineers
Upper Blackstone Water Pollution Abatement District
Blackstone River
River
Singing Dam
Fisherville Dam
Breached Saundersville Dam
Farnumsville Dam
Northbridge USGS Gage
Riverdale Dam
Mumford River
Rice City Pond Dam
WORCESTER
AUBURN
MILLBURY
GRAFTON
UPTON
SUTTON
NORTHBRIDGE
OXFORD
UXBRIDGE
DOUGLAS
WEBSTER
BURRILLVILLE

Table 12: Environmental Restoration Opportunities Identified in the Mumford River Basin

Town	Associated Stream, River, Wetland, or or Impoundment	Location	Project Description
Wetland Restoration and Enhancement			
Northbridge/Sutton	Unnamed Wetland	Abandoned gravel pit east side of 146, south of Mendon Rd., and north of Main St. interchange	Create wetlands and restore upland habitat at large (40+) acre gravel pit. Opportunities to enhance existing wetland may also exist
Sutton	Mumford River	Unnamed wetland northeast of Manchaug Rd. across road from St. Dennis Cemetery.	Removal fill place in wetland and restore degraded riparian buffer.
Uxbridge	Gilboa Brook	Unnamed wetland east of Lackey Dam Road, northeast of Gilboa Brook, and west of 146	Remove fill material and debris placed in and near wetland.
In-stream Habitat Improvement			
East Douglas	Mumford River	Town athletic field adjacent (north) of river.	Construct small in-stream sediment capture pond with clean out to trap coarse sediment.
Uxbridge	Mumford River	Prospect Hill Cemetery area	Install eddy rocks.
Riparian Restoration			
East Douglas	Mumford River	Town athletic field adjacent (north) of river.	Establish vegetated (grass) riparian buffer strip between river and gravel parking lot to treat runoff from parking lot.
Uxbridge	Linwood Pond	Golf Course west of Linwood Pond on Fletcher Rd.	Establish vegetated buffer strip along edge of pond to treat runoff from golf course. Work with golf course to reduce use of pesticides and fertilizer.
Uxbridge	Gilboa Brook	Gravel pit near Gilboa Brook/Mumford River confluence.	Restore riparian habitat disturbed by small (ca. 3 acre) sand/gravel mining operation.
Uxbridge	Mumford River	Abandoned gravel pits south and west of Linwood Pond, west of Rivulet St.	Restore riparian upland habitat and enhance wetlands at 30+ acre site. Investigate possible contamination in ditch draining one of the pits.
Sutton	Swans Pond	South of Purgatory Road, east of Rt. 146.	Establish wooded riparian buffer along north side of pond. Area is currently a mowed field.
Lake/Impoundment Restoration			
Douglas	Gilboa Pond	South of Gilboa St.	Dredge contaminated sediment from 21 acre eutrophic pond.
Douglas	Grays Pond	On Mumford River north of Potter Road	Dredge shallow 6 acre pond to improve fish habitat and improve sediment capture efficiency.
Northbridge/Sutton	Lackey Pond	East of Lackey Pond Rd.	Repair or replace deteriorated dam to preserve ca. 120 acre impoundment that provides highly valued waterfowl habitat.
Northbridge/Sutton	Swans Pond	South of Purgatory Road, east of Rt. 146.	Dredge 31 acre eutrophic pond to improve water quality and reduce aquatic weed problems.
Sutton	Stevens Pond	South of Manchaug Rd.	Repair failing dam to protect fisheries habitat provided by 84 acre pond.
Sutton	Unnamed Pond	Small impoundment on Mumford River in Manchaug, south of Whitin Rd..	Dredge small (< 1 acre) pond to improve sediment capture efficiency and fisheries habitat.
Uxbridge	Whitin Pond	North of Hartford Ave.	Dredge 23 acre pond to improve water and habitat quality. Pond is shallow, highly eutrophic, and has severe aquatic weed problem.
Streambank Stabilization			
East Douglas	Mumford River	Town park/athletic field adjacent (north) of river.	Use bioengineering techniques to stabilize eroding stream bank.
Uxbridge	Mumford River	Vicinity of Prospect Hill Cemetery	Use bioengineering technique to stabilize eroding stream banks. Erosion on one is threatening cemetery along 500 ft. reach.

5.3.1 Solutions to the Loss and Degradation of Wetland Habitat

The problem of the loss and degradation of wetland habitat can be solved by the following physical measures:

1. Removal of fill placed in wetlands;
2. Stabilization of dams/control of water levels;
3. Invasive plant control;
4. Construction of potholes;
5. Restoration of site hydrology.

Wetlands may also be created or expanded through the following actions:

1. Conversion of abandoned gravel pits into wetlands;
2. Raising or lowering of pond levels to expand wetlands habitat;
3. Material removal to expand habitat.

The potential loss of wetlands and further degradation of wetlands can be prevented by:

1. The repair of unsafe dams with wetlands habitat formed behind them;
2. The repair of unsafe dams upstream of significant waterfowl habitat;
3. Land use protection, including the critical adjacent riparian habitat (non-physical).

A discussion of each of the solutions is provided in the following sections.

5.3.1.1 Removal of Fill Placed in Wetlands. There are many opportunities in the Blackstone Basin to restore large and small areas of wetland destroyed or degraded by fill material. Sites are typically adjacent to homes or businesses filled for oversized parking areas, storage areas, or simply to dispose of waste material. In many cases wetlands could be restored with minimal impact to the owner.

Site restoration involves the removal of debris and fill material to restore original surface elevations and wetland hydrology. Hydric soil is likely to remain underneath the fill and will support wetland vegetation once the fill is removed. Seeding with a wetland seed mix and planting wetland shrubs and trees would accelerate the restoration of vegetation.

Restoration of wetlands would enhance water quality (pollutant attenuation), increase wildlife habitat, and attenuate flood flows. The individual benefits of restoring small sites may be minimal, but cumulative benefits could be significant. Adjacent development would greatly limit the wildlife habitat value of restored areas. On a cost basis, restoring a few large, relatively isolated sites would probably be more beneficial to wildlife habitat than restoring numerous smaller sites. The only adverse impacts of removing fill would be the relatively short term construction related impacts (noise, dust, and increased traffic) and the cost. The cost of removing fill is largely based upon its volume. Assuming fill material is suitable for use as clean fill or disposable as non-hazardous solid waste, restoration would generally cost between $25,000 and $50,000 per acre.

The prototype projects described for the Lonsdale Drive-In and the Riverdale Gravel Pit (see Chapter 6) demonstrate restoration using this solution.

5.3.1.2 <u>Stabilization of Dams/Control of Water Levels.</u> The draining of wetlands for reasons associated with dam safety has been identified as important from a watershed perspective. Part of the solution to this problem is the stabilization of dams that have resulted in the creation of these wetlands. The stabilization of an unsafe dam presently supporting wetlands behind it will ensure the continued presence of that wetland, and those downstream that would be impacted or destroyed by the upstream dam's failure.

In some cases, the restoration of a pool alone is not enough to restore the health of the wetland since the draining of these wetlands is accompanied by the destruction of the emergent vegetation in the wetlands. In such cases, mudflat conditions must first be supported, and water levels controlled over several growing seasons while the vegetation re-establishes itself (the planting of "starter" vegetation may also be needed). A new outlet configuration may be necessary in order to obtain the desired water levels, and ensure that the levels be tightly controlled.

The prototype project described for Fisherville Pond (see Chapter 6) demonstrates restoration using this solution.

5.3.1.3 <u>Invasive Plant Control.</u> Invasive plants impacting wetland habitat in the Blackstone River basin include purple loosestrife, reed (*Phragmites*), and buckthorn. Control measures are most appropriate in small areas where rare species or community types are threatened. Control of *Phragmites* to prevent degradation of large emergent wetlands is also appropriate.

Eradication of purple loosestrife is extremely difficult because of regrowth from seed and rhizomes. Small populations can be controlled by repeated application of a non-selective herbicide, or by weeding and/or cutting. Over the long-term, several insect species native to Europe are being released in eastern United States and may provide effective control. Release of biocontrol agents at the Valley Falls Marshes is planned for the 1997 growing season. *Phragmites* can be eradicated by repeated application of herbicide (glyphosate). For small stands, the herbicide can be applied using a backpack sprayer, sponge applicator, or squirt bottle. A combination of spraying and cutting may yield the best results. Care must be made in its application or else other vegetation in the area will be killed. The herbicide binds to soil quickly and is non-toxic to the aquatic environment. Additionally, it quickly degrades and has no long-term impact on community redevelopment. Repeated treatments over a few years are typically required for complete eradication. Herbicide application costs about $500 - 1,000 per acre. For small stands in sensitive areas where the herbicide cannot be used, long-term control, but not eradication, is possible using mechanical removal (weeding) or cutting. *Phragmites* control by cutting typically costs from $1,000 to $10,000 per acre per year. Mechanical control and cutting operations involve some trampling of adjacent vegetation. Eradication of buckthorn is difficult. Small populations can be controlled by repeated cutting and application of the herbicide.

There are no prototype projects planned that illustrate this remedial measures. *Phragmites* stands have been identified at numerous locations in the basin, including Fisherville Pond, Grafton, Massachusetts.

5.3.1.4 **<u>Construction of Potholes.</u>** Potholes are small areas of open water, typically one-quarter acre or less, constructed primarily for waterfowl habitat improvement. Potholes can be constructed within existing wetlands (e.g. wet meadow) or in adjacent upland areas. Potholes provide brood and foraging habitat for dabbling ducks, foraging habitat for wading birds such as heron, and habitat for aquatic life. Potholes in upland areas can function as vernal pools and provide important breeding habitat for reptiles and amphibians. For dabbling ducks, ponds should have a maximum depth of about 3 feet, with much of the pond 6 to 18 inches deep. In areas where groundwater levels drop during the summer, water retention can be enhanced by lining the pond bottom with clay or compacted stone dust. Excavated material is usually disposed on site and seeded. Impacts of construction are short-term, primarily due to construction of access roads and construction-related noise.

The prototype project described for Fisherville Pond (see Chapter 6) demonstrates restoration using this solution.

5.3.1.5 Restoration of Site Hydrology. Restoration of sites with altered site hydrology caused by restricted drainage involves installation of properly sized culverts to restore, or partially restore pre-existing hydrologic conditions. Removing drainage restrictions alters habitat type (e.g. from emergent to scrub-shrub wetland), thereby increasing habitat value for some plant and animal species, and decreasing it for others. At most sites the environmental benefits of removing or reducing restrictions is minimal and does not justify project costs. However, in some cases, restoration of site hydrology is justified based on benefits to rare species habitat or rare community types. Installing enlarged culverts may cause short-term construction-related impacts, especially the disruption of traffic, and may result in an increase in downstream flooding.

Restoration of sites drained for agriculture can be accomplished by plugging ditches or drains, and planting appropriate vegetation. Restoration of drained areas that are highly developed is not practical, however. Restoration of ditched or drained wetland areas converted to agriculture would restore wetland plant communities, improve wildlife habitat, enhance water quality (pollutant attenuation), and attenuate flood flows. Negative impacts of the removal of drainage ditches are the potential impacts on wells, septic systems, and structures constructed within or near the drained area.

There are no prototype projects planned that illustrate this remedial measures.

5.3.1.6 Conversion of Abandoned Gravel Pits into Wetlands. The Blackstone River basin is dotted by numerous gravel pits, many of which have been abandoned. These appear to offer an excellent opportunity for wetlands expansion to offset watershed deficits in wetlands. The methodologies to be used in creating these wetlands are nearly the same as those for removal of fill placed in wetlands. The reader is referred to Section 5.3.1.1 for a discussion of these restoration measures.

The prototype project described for the Riverdale Gravel Pit (see Chapter 6) demonstrates restoration using this solution.

5.3.1.7 <u>Raising or Lowering of Pond Levels to Expand Wetlands Habitat.</u> Water levels may be raised at existing dams in order to create additional shallow wetlands areas. Creating additional wetlands habitat by raising water levels would be partially offset by the conversion of current wetlands areas favored by waterfowl (i.e. with depths ranging from 6 to 18 inches) into deeper open water areas favored by fish. The value of this action therefore hinges critically on the topography of the pond site. There are numerous other tradeoffs which need to be considered, many of which are similar to the tradeoffs associated with dams (see side discussion on pros and cons of dams). Increased water levels may reduce weed problems (e.g. invasive *Phragmites* stands), reduce sediment resuspension caused by high flows, reduce nutrient release from sediment, enhance recreational boating, and improve aesthetics. Raising the water level should also benefit downstream riverine habitat by improving impoundment sediment capture and nutrient removal efficiency, and reducing wet weather sediment resuspension. On the negative side, however, raising the water level would adversely impact vegetation until plant communities shifted in response to new conditions. Long-term impacts would be minimal. Emergent vegetation would eventually colonize newly flooded areas and submerged vegetation would colonize areas formerly vegetated with emergents. Some upland habitat would be flooded and permanently lost. At some impoundments significant cultural resources could be inundated (e.g. the Blackstone Canal locks at Rice City Pond). In some cases (e.g. Riverdale Pond), it may be appropriate to lower water levels in order to convert open water into marsh.

Water depth can be raised by adding flashboards or by making structural modifications to a dam. Flashboards are adequate only if relatively small changes in water level are desired. Structural modifications can be cost prohibitive and may not be cost effective. Flashboards may be cost effective if raising the water level only a foot or two.

The prototype project described for the Rice City Pond (see Chapter 6) demonstrates restoration using this solution.

5.3.1.8 <u>Material Removal to Expand Habitat.</u> Wetlands may be expanded through material removal using either mechanical or hydraulic techniques. The reader is referred to the side discussion of material removal. Material removal is often very expensive, in part due to the need for disposal areas. Material disposal issues are often highly controversial.

The prototype project described as Fisherville Pond Alternative 2 (see Chapter 6) demonstrates restoration using this solution.

5.3.2 Solutions to the Loss and Degradation of Riparian Habitat

The problem of the loss and degradation of riparian habitat can be solved by the following physical measures:

1. Establishment of a forested buffer zone;
2. Planting of grassland habitat;
3. "Greening" of erosion control structures;
4. Bioengineering of streambanks;
5. Zoning and greenway legislation, or land purchase/easement.

The benefits and costs of each of the solutions are discussed in the following sections.

5.3.2.1 Establishment of a Forested Buffer Zone. There are numerous opportunities to restore large areas of riparian habitat in the Blackstone River basin into forested buffer areas, and wooded areas maintained adjacent to streams, rivers or impoundments. Sites identified in this study range in size from several acres to about 50 acres. Areas with potential for restoration include abandoned gravel pits, agricultural fields, abandoned or unused industrial or commercial property, automobile junk yards, and other highly disturbed sites. Restoration plans would vary widely depending on site conditions, restoration objectives, and available financial resources.

Reforestation of fragmented riparian zones can re-create corridors linking isolated patches of habitat. Species that would benefit through the restoration of the riparian areas include reptiles such as the spotted turtle and wood turtle, small mammals including raccoon and muskrat, and birds such as the great blue heron and kingfisher. These linkages help maintain biodiversity and the genetic viability of small, isolated populations in an otherwise heavily developed landscape

Restoration of riparian buffers also provides important support to the aquatic food chain through input of detritus (leaves and woody debris). Large woody debris such as trunks and root masses enhance aquatic habitat structure by providing cover and reducing scour. In small

The Pros and Cons of Dams and Ponds

Most dams in the watershed were constructed for water storage or hydropower purposes. Some still serve their original purpose, however, many don't and, in fact, many are believed abandoned. Many of the dams are in fair to poor shape. Their failure would endanger human lives and the washout of sediments would smother ecological habitat in downstream areas. Because of their historical importance (several currently listed on the National Register), and the basin's National Heritage Corridor status, dam removal opportunities are probably limited.

Although the ponds created by the dams originally provided considerable open water habitat, with the passage of time the ponds have silted in with sediment. This has resulted in a change of much of the habitat into shallow emergent habitat, particularly attractive to waterfowl. There are many locations where dams play a crucial role in supporting/providing wetlands.

When not fully sedimented, the ponds serve as toxic contaminant sinks and reduce turbidity by physical processes such as settling. Although this benefits downstream areas, including Narragansett Bay, the settled sediments are likely to become resuspended at some point in time, either during high flows, or when either the dam or an upstream dam fails. Other water quality parameters impacted by dams include dissolved oxygen, temperature, and nutrients. Oxygen is typically depleted in the ponds due to the oxygen demands placed by sediment contaminants and by algae blooms. This may be offset by the reaeration that occurs over the spillways. Temperature is increased in ponds due to the lengthening of detention time (compared to that of free-flowing streams) and warming by the sun. Nutrients are typically retained in ponds, often causing algal blooms and oxygen deficits.

Dams and ponds offer a number of other tradeoffs. Ponds offer flat water recreational opportunities (fishing and boating) different from the whitewater recreational opportunities that they displaced. Ponds serve to attenuate floods, and short-term fluctuating flows such as those believed caused by the mainstem river's hydropower facilities. Attenuation of floods by ponds in the Blackstone basin is probably limited as are opportunities for flow augmentation, however, due to limited storage availability.

Dams block both boat and fish passage. This is especially important as it pertains to anadromous fish that need to freely travel from the ocean habitat areas to upstream areas where they spawn and back. Fish passage facilities may be implemented in lieu of dam removal, however, fish passage facilities are typically expensive, even more so when historic status dictates costly mitigating features.

Given the habitat and recreational value of many impoundments and their historical significance, widespread removal of dams to restore free-flowing riverine habitat is not

The Pros and Cons of Dams and Ponds (continued)

recommended. As dams age and the need for major repairs arise, the positive and negative impacts of maintaining individual impoundments should be assessed. In some cases it may be appropriate to remove or breach dams. In others, such as Fisherville Dam, it will be most beneficial to repair the dam. The needs and financial concerns of the owner as well as the public should be weighed in the decision on dams. This report further recommends that the overall needs of the basin be considered in the equation. The principal benefit of removing a dam is the restoration of stream and riparian habitat in the impounded reach. This may, however, result in the loss of waterfowl and warmwater fisheries habitat in the pond and increased bank and channel erosion. There are economic costs to both dam rehabilitation/ maintenance and dam removal. It should be noted that removal of a dam, particularly on the mainstem river, is likely to trigger the regulatory agencies into requiring the stabilization or remediation of sediments behind the dam. Breaching some dams in the Blackstone would additionally adversely impact historic resources.

Material Removal

Many of the projects (Fisherville Pond, Singing Dam, Lonsdale Drive-in, etc.) discussed in this study require the removal of materials from the bottom of a river channel and/or a pond. The materials to be removed are typically combinations of inorganic sediments (clay, silt, gravel and stone), organic sediments (silt and peat), vegetation and debris. They may or may not be contaminated. If the water level can be lowered in the proposed removal areas, conventional land based excavating equipment can be used. If the water level can not be lowered, construction of temporary access roads (shallow water only) is needed to operate conventional excavating equipment or water based equipment can be used. Water based equipment could be a conventional excavator resting on a float with additional floats for hauling material or a hydraulic dredge resting on a float. A hydraulic dredge sucks loose material and water up and then pumps them to a disposal area.

Material resuspension, disposal, contaminated sediments and cost are key issues to address when removing materials from the bottom of river channels and ponds. Lowering the water and reducing the velocity of the water in the proposed removal areas usually reduces the amount of material resuspension. Silt curtains are often placed around removal areas to reduce the amount of resuspension. Conventional excavating equipment are outfitted with toothless buckets and hydraulic dredges are outfitted with specially designed heads (cutter heads, horizontal augers, matchboxes, etc.) to further reduce resuspension. All material removal requires a final disposal area and most requires a temporary disposal area. The temporary area is used to dewater the material before it is taken to the final disposal area. Disposal areas associated with water based material removal are typically larger and more expensive than with land based removal. The costs associated with reducing resuspension, developing disposal areas, dealing with contaminated sediments and environmental issues often make material removal unattractive.

streams, riparian vegetation provides shade which moderate stream temperature and protects native populations of brook trout and other cool water species.

Restoration of a forested buffer zone also results in incremental improvements in water quality through the removal of sediment and nutrients from runoff and overbank flow, an enhancement in the value of adjacent protected habitat and nearby habitat islands, improved aesthetics, and flood attenuation. Forested buffers can also improve water based recreation by screening undesirable views of adjacent developed areas.

If a site is already wooded, buffer strips can be established by preserving a "no-cut/no-mow" zone. At disturbed or degraded sites, soil preparation and the planting of trees and shrubs is useful to augment natural regeneration. Site engineering work may be needed to encourage sheet (as opposed to channel) flow across the buffer strip and enhance the treatment of stormwater runoff. Drawbacks to establishing forested buffers may include the loss of land, most often agricultural, obstructed views of water, and the short term impacts associated with any construction project (noise, dust, and increased traffic).

The cost of providing forested buffer strips depends on the extent that the site is degraded, the need for soil preparation, and the need for site engineering work to encourage sheet flow of stormwater runoff. Most restoration efforts are likely to cost less than $25,000. Project costs can be reduced if partial development of the site is possible without significantly impacting restoration objectives.

The prototype project described as Fisherville Pond (see Chapter 6) demonstrates restoration using this solution.

5.3.2.2 <u>Planting of Grassland Habitat.</u> Opportunities for the planting of grassland habitat are the same as those for a forested buffer zone. Grassland buffer strip habitat also offers significant ecological benefit, albeit different than those of forested buffer strip habitat. Grassland is one of the most threatened habitat types in New England, probably because of the lower development costs associated with this type of land. Restoration of grassland habitat costs less than that of forested buffer habitat.

The prototype projects described as the Lonsdale Drive In Alternative 2 and the former Rockdale Pond revegetation (see Chapter 6) demonstrate restoration using this solution.

5.3.2.3 **<u>"Greening" of Erosion Control Structures.</u>** This restoration measure has potential application at all four Army Corps of Engineers LPPs in the Blackstone River basin and at the shore and bank protection project in Millbury. LPPs are faced with stone protection to reduce the risk of erosion and migration of materials through dikes. Corps regulations require regular removal of woody growth to prevent damage to the protection during high flows. Recent changes in Corps philosophy make it more acceptable to plant vegetation (typically small willow trees) in the voids of the stone protection provided that the vegetated area is not on a dike slope, does not endanger the integrity of a slope, and does not impact the flood water levels and velocities in the area. If the estimated flood water velocities are high, it is imperative the larger trees (greater than two inches in diameter) on channel slopes are cut annually so they do not topple during a flood event and leave erodible root craters. Ongoing studies may eventually allow the vegetation of the dike slopes with species that have shallow root systems. "Greening" of Corps LPPs could be considered for further study in the feasibility phase.

5.3.2.4 **<u>Bioengineering of Streambanks.</u>** Bioengineering techniques integrate vegetation, wood, rock, geotextiles, and other materials to provide effective, streambank erosion control with a durable, natural-looking appearance that enhances aesthetics. Although bank stabilization is the principal goal, enhancement of fish and wildlife habitat, water quality, and aesthetics, are important design considerations. Bioengineering is a potentially useful tool in controlling bank erosion when expected flows are less than about 10 to 12 feet per second (draft unnumbered Engineering Manual, Corps, 1997). In such situations, it is a viable alternative to traditional rock riprap, gabions, bulkheads, and other hard "structures" which provide little fish and wildlife habitat value and poor aesthetics. Refer to the side discussion of bioengineering techniques.

The success of a bioengineering project depends on protecting the toe of the slope from further erosion. Depending on velocities, rock, logs, coir rolls, root wads, and other materials can be used at the toe. Selection of plant material above the toe is also important, with preference given to native species tolerant of flooding. Species are chosen consistent with their natural habitat, often using streambank zones that correspond with microhabitats of native plant species in local stream environments. Where possible, both herbaceous and woody species are used with grass or grass-like plants, e.g., sedges, rushes, grasses, in the lower-most zone, then shrubby, woody vegetation in the middle zone, and for the most part, larger shrubs and trees in the upper-most zone. These zones are respectively called the "splash, bank, and terrace zones".

Bioengineering Techniques

Several bioengineering techniques are suitable for use in the Blackstone basin. In lower velocity areas, coir geotextile rolls planted with emergent vegetation can effectively stabilize eroding areas. Areas behind the coir rolls are filled with soil and planted. Emergent plants can be grown from seedlings within the rolls at the nursery or transplanted into the roll in the field.

Brush matting is a thick layer (or mattress) of interlaced live branches held in place on a embankment by stakes. The branches in the mattress are usually about 2 to 3 years old, sometimes older, and 1.5 to 3 m long. They are placed perpendicular to the bank with their basal ends inserted into a trench at the bottom of the slope in the splash zone, just above any toe protection, such as a rock toe. After placement they are covered with soil to promote sprouting. Willows and other species which sprout well from cuttings must be used.

Wattling is a cigar-shaped bundle of live, shrubby material made from species that root very quickly from the stem, such as willow and some species of dogwood and alder. Bundles are staked along the embankment parallel to the stream and covered with soil. Use of dormant plant material is preferred. Wattling and brush matting are sometimes used together.

Coir fiber mats can be used to stabilize embankments. These can be planted in the field or prevegetated at the nursery. Mats must be carefully tied in or keyed into the toe material.

Dormant cuttings, sometimes called "live stakes," involve the insertion and tamping of live, rootable cuttings into the ground, geotextile substrate, or in rock rip rap (joint planting). In higher velocity streams, such as over 5 fps, this method usually is applied in the splash zone with a combination of other methods, such as the brush matting or root wads. Dormant cuttings can vary in size, but are usually a minimum of 0.5 in. in diameter at the basal end. Plantings can occur at the water line as in the splash zone, up the bank into the bank zone, and on top of the bank (terrace zone) in relatively dry soil, as long as cuttings are long enough to reach into the mid-summer water table.

Log revetments can be used to protect eroding embankments. Typically logs are secured with cables that are looped around the logs and then are fastened to dead men in the bank. Rock may be needed at the toe of the structure to prevent scour. A geotextile coir roll can be placed above the top log in the revetment and backfill placed behind the logs. The coir logs and backfilled and then planted with appropriate vegetation.

Root wads can be used to provide an interlocking wall protecting the streambank from erosion. Voids behind the root wads are filled with a soil mix and planted. The root

Bioengineering Techniques (continued)

mass should be a minimum of 5 ft in diameter and angled slightly upstream towards streamflow. The bottom two-thirds of the root wad should be in water during the growing season. Live or dead trees can be used.

Stabilization of streambanks with plantings, live branch packings, or fascines would increase habitat and improve water quality. Vegetative techniques provide a durable, natural-looking appearance while providing many habitat benefits. The widely spreading branches of the plants would reduce stream velocity and remove sediments while the rapidly and widely spreading root systems would stabilize the banks, reducing sediment loads from entering the stream system and from further degrading the benthic habitat. Overhanging vegetation would provide important cover and food sources in addition to improving temperature regimes and providing nutrient sources through detrital pathways. Leaf fall is very beneficial to the benthic environment and supports many species of bacteria and invertebrates important to aquatic systems.

5.3.2.5 <u>Zoning and Greenway Legislation, or Land Purchase/Easement.</u> This activity is the responsibility of non-Federal agencies. Protection of land in such a manner is obviously helpful in protecting riparian habitat. No further discussion is presented here.

5.3.3 Solutions to the Loss of Anadromous Fisheries

The problem of the <u>loss of anadromous fisheries</u> can be solved by the following physical measures:

1. Removal of dams or other barriers;
2. Addition of fish passage facilities to dams/modifications of spillways;

In either case, it is necessary to begin at the downstream end of the river and work upstream. It makes little sense to provide fish passage to areas providing little habitat value. In the case of the Blackstone, there is little habitat value downstream of the Valley Falls Marshes. It therefore would be necessary to provide fish passage at all four of the lower four dams. A combination of the two physical methods may be applicable, with removal of some dams, and the provision of fish passage around others.

Restoring anadromous fish to the watershed would increase aquatic diversity as well as human recreation. Species that would benefit from the removal of fish blockages include anadromous fish such as American shad, river herring including alewife and blueblack herring, and Atlantic salmon. Other fish types would benefit also, including migratory fish such as the white sucker, white perch and striped bass in the lower reaches; local resident warm water habitat fish such as largemouth bass, smallmouth bass, bluegill, yellow perch, chain pickerel, northern pike, among others; local resident cold water habitat fish such as brook trout, brown trout, and rainbow trout in the upper tributaries. The various warmwater and coldwater forage species such as Cyprinids (e.g. dace and shiners) would also benefit.

5.3.3.1 <u>Removal of Dams or other Barriers.</u> Anadromous and residential fish passage may be restored through the removal of dams or other barriers that prevent upstream and downstream fish passage. Breaching a dam is a practical alternative when the dam has no purpose or lesser value compared to that of free passage. Breaching a dam solves both upstream and downstream fish passage needs. However, other issues, such as the release of contaminated sediments, may be critical in determining whether this solution is practical. Removal of dams involves numerous tradeoffs, some of which are discussed in Section 5.3.5.1.

5.3.3.2 <u>Addition of Fish Passage Facilities to Dams/Modifications of Spillways.</u> Fish passage technology has improved greatly in recent years. Several New England states have active and successful programs providing passage for migratory fish. For example, in Massachusetts, nearly 130 fishways maintain migrations on approximately one hundred tributaries. On the Connecticut River, migratory fishes have been restored to 174 miles of historic habitat as a result of fishway operations at three dams.

A common solution is to install a fish passage facility, or fishway, to allow fish to pass over or around the dam during their upstream migration. On smaller blockages, such as those on the Blackstone River, a fish ladder can be used. A fish ladder is an inclined water channel structure with a series of baffles or weirs which interrupt and slow the flow of water. The fish swim up the ladder just as they would natural rapids. Special considerations in design must be made at hydropower facilities in order to minimize the passage of fish through the hydroelectric turbines. It is also recognized that fish passage facilities may result in some losses in the profitability of the hydropower operations. On small tributaries, it may be possible, however, to simply retrofit structures such as culverts to provide the gradient and flow necessary for fish passage.

Other methods of passage are probably less likely on the Blackstone for economic and other reasons. These methods include locks or lifts (elevators) except possibly at the relatively large Thundermist Dam, or physical transportation (trucking) around one or more dams.

Downstream fish passage facilities are also required at all dams on the Blackstone where upstream passage has been provided. Most typical and simplest is to spill flows over the dam spillway by placing a notch in the spillway usually adjacent to the upstream fishway exit channel and providing for a plunge pool for the fish to safely fall into. At the other end of the scale, more sophisticated physical screening devices (e.g. angled bar racks) and light- or sound-based guidance measures are being studied to bypass downstream migrating fish with a minimal loss of water that could otherwise be used for power generation.

Costs of providing fish passage are highly variable, depending on site specific conditions and the required type of structure. Due to the historic status of the dams on the Blackstone, costs are likely to be high. All prudent and feasible alternatives to fish passageways would need to be considered. In some cases, passageways may not be allowed or would have to be significantly altered.

The prototype project described as Fish Passage at the Lower Four Dams (see Chapter 6) demonstrates restoration using this solution.

5.3.4 Solutions to the Loss and Degradation of Lake and Pond Habitat

The problem of the loss and degradation of lake and pond habitat can be solved by the following physical measures:

1. Control of Nutrients;
2. Invasive Plant Control;
3. Dredging, or the raising of dams;
4. Construction of sediment capture basins;
5. Dam Stabilization.

The benefits and costs of each of the solutions are discussed in the following sections.

5.3.4.1 Control of Nutrients. Nutrients are best controlled by tightening the NPDES permit limits of point sources, and by controlling non-point sources through Best Management Practices (BMPs). BMPs are methods that can effectively reduce stormwater pollution before it is washed off the streets by rainfall. These practices are only a partial solution to the water quality problems but can reduce loadings (typically, zero to 5 percent of the total suspended solids load to the storm drain system) and augment other remedial measures. BMPs which could be adopted by communities in the Blackstone River Basin include: public information/education, impervious surface restrictions for any new construction within the watershed, catch basin/street cleaning in urban areas, illegal dumping/illicit connection controls, site controls at construction sites (especially near wetlands or streams), and fertilizer/pesticide management.

Stormwater treatment ponds can be created to treat stormwater from small urban runoff areas. Retention ponds usually contain a permanent pool whose main purpose is to retain sediment, an emergent marsh and deepwater pool to remove nutrients and contaminants.

Existing stormwater detention ponds can sometimes be retrofitted to improve sediment capture efficiency and nutrient retention. Properly sized pond systems can remove a high percentage of BOD_5, organic nutrients, and trace metals. Ponds also provide habitat for fish and wildlife. The systems typically require a few acres of land.

The sediment capture system portion of the prototype project described for the daylighting of Beaver Brook (see Chapter 6) demonstrates restoration using this solution.

5.3.4.2 Invasive Plant Control. Control of European water milfoil is extremely difficult. Control measures are most appropriate in small areas where rare species or community types are threatened. Techniques which have had some success include herbicides, winter drawdowns, and dredging. Eradication of Asiatic Knotweed is extremely difficult because of regrowth from seed and rhizomes. Small populations can be controlled or eliminated by repeated application of rodeo, weeding, and/or cutting. Replacement of knotweed with a more diverse plant community would enhance wildlife habitat value. Both species tend to crowd out other plants and their control would increase local plant species diversity.

5.3.4.3 Dredging, or the Raising of Dams. The dredging of a pond is one way to restore the depth of a pond. Raising the water surface elevation of a pond is another way, typically by raising the height of the dam and associated outlet features. The problems and the solutions are the same or similar to those for the loss and degradation of those wetlands created by dams. These two methods were discussed in Sections 5.3.1.7 and 5.3.1.8.

5.3.4.4 Construction of Sediment Capture Basins. This solution is similar to that discussed in the control of nutrients through stormwater treatment ponds. Wherever water velocities slow, sediment settles out. This is often undesirable from a habitat standpoint. However, the settling of sediments tends to benefit downstream areas. Sediment capture ponds can be either large- or small-scale.

Prototype projects demonstrating restoration using this solution include the large-scale Singing Pond Sediment Capture Pond and the small-scale sediment capture pond in the Daylighting of Beaver Brook (see Chapter 6).

5.3.4.5 **Dam Stabilization.** This solution will prevent the loss of ponds and lakes. It has already been discussed as a solution to the loss of wetlands created by dams (Section 5.3.1.2).

5.3.5 Solutions to the Loss and Degradation of River/Stream Habitat

The problem of the loss and degradation of river/stream habitat can be solved by the following physical measures:

1. Removal of dams to re-expose river habitat;
2. Channel restoration/modification and/or construction of instream habitat improvements;
3. "Daylighting" of streams;
4. Eliminate hydropower fluctuations;
5. Re-water hydropower bypass reaches.

The benefits and costs of each of the solutions are discussed in the following sections.

5.3.5.1 **Removal of Dams to Re-expose River Habitat.** Most dams in the Blackstone River basin have granite block spillways which can be easily breached or removed to restore free flowing conditions. Because most impoundments contain a significant amount of accumulated sediment, measures must be employed to prevent sediment from washing out and impacting downstream habitat after the dam is breached. Dredging sediment from a portion of the impoundment prior to breaching the dam may be needed to avoid significant downstream impacts. After the dam is breached, seeding exposed mudflats and bioengineering to stabilize eroding embankments may also be required.

Costs of dam removal are highly variable. Breaching a dam can be inexpensive but overall project cost costs can be high if sediment must be dredged from the impoundment prior to dam removal. Project costs may also be high due to planning/permitting costs and costs to restore riparian habitat, stabilize eroding embankments, and remediate contaminated sediment. Breaching of dams, however, avoids costs associated with long-term maintenance and major repairs. Refer to the side discussion on the pros and cons of dams.

5.3.5.2 Channel Restoration/Modification and/or Construction of Instream Habitat Improvements. Some channelized segments in the watershed would best be repaired by physically restoring the channel to optimum flow, habitat, and energy-dissipating regimes. Several methods would likely be required to attain the desired biological and aesthetic effects.

In many cases, channel modification would be necessary to realign the stream to its natural geometry. This would involve extensive excavation and earthwork to develop a sinuous meandering pattern with enhancement of adjacent floodplain terraces and/or riparian areas (e.g. fringe wetlands). The hydrology and morphology of urban streams and their floodplain/riparian areas (including fringe wetlands) alter the dynamic equilibrium between sediment loads entering and leaving a stream system. Streams compensate for these manmade alterations with a new equilibrium achieved by channel widening or deepening. A more natural effect could be obtained by diverting flows, particularly floodflows, to adjacent floodplain/bottomland areas. This may be accomplished by removing natural or manmade berms, or by excavating or regrading the inside curved bends of a river to allow the adjacent areas to be periodically inundated.

Multi-stage channels should be used where stream restoration would benefit a previously modified or otherwise heavily impacted channel. Channelized segments, often with fill placed along the channel, typically have narrow flow widths even during high flow. Further modifications of these reaches can keep necessary flood conveyance capacity while also providing benefits including improved water quality, wildlife habitat, and aesthetics and reduced erosion potential. Restoration can be accomplished by excavating terraces on either side of the channel to increase the cross-sectional area available for high flows. If the bottom of the existing channel is narrow, it may be able to be preserved as the low-flow channel, especially if it has stable course substrates. The excavated terraces should be planted with woody vegetation.

Restoring streams through the return of pool/riffle complexes and the stabilization of stream banks (bioengineering), would help return natural processes and improve aquatic habitat. Construction of pools and riffles through placement of wing deflectors, riprap, and boulders, or channel modification would restore the normal character of the river bottom by removing sediments and lowering siltation of the larger, higher quality substrates. Other structural measures used to increase habitat variety could include rock islands, cover logs, rock vortex weirs, gravel placement, and channel blocks. The newly established gravels and cobbles would greatly enhance the stream's habitat value and its suitability for fish and macroinvertebrates. Constricting,

Benefits of Restoring Natural Functions

The return of pool riffle complexes and stream meanders, and the constriction of widened channels would increase stream miles and quality of habitat in each basin, increasing biodiversity. Ecological systems would become more efficient in cycling nutrients and transferring energy, and result in improved water quality in the basin and ultimately Narragansett Bay.

Several functions would result from the reduction in stream-created sediment and associated pollutants, including the reduction of downstream impacts and eutrophication of receiving bays. Removal of habitat-destroying sediment would greatly increase the quality of benthic habitat throughout the basin. The increase in diversity and biomass of new aquatic organisms would provide important links in the aquatic food webs and nutrient cycling. Fish species that would benefit through the restoration of the basin stream systems are: anadromous fish such as American shad, river herring (alewife and blueblack herring), and Atlantic salmon; migratory fish such as the white sucker, white perch and striped bass in the lower reaches; local resident warm water habitat fish such as largemouth bass, smallmouth bass, bluegill, yellow perch, chain pickerel, northern pike, among others; local resident cold water habitat fish such as brook trout, brown trout, and rainbow trout in the upper tributaries; and the various warmwater and coldwater forage species such as dace and shiners. Other aquatic or aquatic related organisms that would benefit include: amphibians such as the green frog; reptiles such as the painted turtle; small mammals including raccoon, muskrat, and otter; and wading birds and waterfowl such as great blue herons and black duck.

The addition of instream habitat structures would provide the necessary physical structure required to improve aquatic conditions for fish and invertebrates. Existing channels that have widened due to increased flow would greatly benefit from the addition of habitat structures. Wing deflectors, rock vortex weirs, channel blocks, and boulder placement would help to constrict the flows of the widened stream and would scour away sediments. Scouring would produce deeper pools while rocks would provide permanent cover, valuable to fish and invertebrates. This cover would provide diversity to microhabitats of the substrate, allowing for more suitable areas for resting and feeding. Modification of the ecosystem structure would result in the return of a naturally appearing stream bottom with eddies, pools, riffles, and runs. The creation of these different types of habitat structure would increase the functional characteristics of the stream systems. Following the increase in benthic habitat, functions such as biomass production, food web support, nutrient cycling and transport, and habitat cover would be increased. Pollution intolerant invertebrate populations would also increase, including members of the mayfly family and stonefly family.

deflecting, or diverting the flow with instream structures produces scours, removes fine sediments, increases dissolved oxygen, produces a variety of microhabitats and adds food and complexity to the foodweb.

Temporary adverse impacts such as an increase in turbidity may occur within the stream during construction due to the grading of banks or placement of material. Some sediment habitat may also be temporarily converted to stone or gravel habitats through the placement of habitat structures or by a change in stream velocity, which may scour sediments. Instream impacts would be avoided by following best mangement practices, working within the streams only when necessary, and staying out of the streams during critical periods. The environmental benefits received from the restoration measures would greatly outweigh the temporary impacts.

5.3.5.3 **"Daylighting" of Streams.** "Daylighting" involves the restoration of covered reaches of streams to open channels. In the past, streams were often channelized in closed conduits below the ground surface, typically to remove odor and health hazards posed by degraded streams in urban communities. The principal benefit of daylighting streams is the restoration of the former stream and adjacent riparian habitat. Restoring the stream through the return of pool/riffle complexes and the stabilization of the stream banks would help return the natural structure and function of the stream and improve aquatic habitat. Daylighting former closed stream reaches may first involve confronting any lingering issues of water quality and aesthetics. Hydraulic issues must also be addressed, including flooding in both the daylighted and downstream reaches.

Costs of daylighting are highly variable depending on the size and width of the stream to be daylighted, development (roads, buildings, etc.), and the other water quality and flood related concerns to be addressed.

The prototype project described as Daylighting of Beaver Brook (see Chapter 6) demonstrates restoration using this solution.

5.3.5.4 **Eliminate Hydropower Fluctuations.** The solution to stopping hydropower-caused streamflow fluctuations appears straightforward. Licenses granted by the Federal Energy Regulatory Commission (FERC) to the hydropower operations stipulate run-of-river operating conditions, i.e. inflow is equal to outflow on an instantaneous basis. FERC should ensure that these license conditions are being met and the problem will be solved.

The Streamflow Task Force of the Blackstone River Valley National Heritage Corridor Commission's Environmental Subcommittee is in the process of requesting FERC's involvement to insure that the license stipulations are met. Complicating matters are a lack of streamflow gages to pinpoint fault(s), a lack of written hydropower operating plans, and old non-variable speed (simple on-off operation) turbines in one or more cases. FERC has met with the hydropower operators and those on the Task Force in the past year, and steps are being taken to insure eventual compliance. The problem of hydropower-caused fluctuating flows is likely to be successfully addressed in the next few years or sooner.

5.3.5.5 Re-Water Hydropower Bypass Reaches. The problem of hydropower-caused dewatered reaches can be solved through the FERC licensing process. Current FERC licenses do not, in all cases, provide for adequate flows in the reaches bypassed by hydropower generating features. The hydropower facilities were all relicensed in the early 1980's (with the exception of the Riverdale licensing in 1987) for a period of 40 years. Due to the poor water quality conditions at the time of relicensing, FERC did not stipulate bypass flows adequate to protect a healthy aquatic community.

There are two ways to rewater the bypass reaches: through a re-opening of the permits by FERC, or through voluntary releases by the facilities. The Streamflow Task Force of the Blackstone River Valley National Heritage Corridor Commission's Environmental Subcommittee is currently in the process of documenting the dramatic improvement in water quality and health and diversity of the aquatic population in order that FERC be petitioned to re-open the licenses to require additional flows to be bypassed in support of the habitat values offerred by the now-bypassed segments.

5.3.6 Solutions to the Improvement of Degraded Water and Sediment Quality

The problem of degraded water and sediment quality can be solved by several measures, all previously discussed in prior sections of the report. The solutions to these problems are:

1. Tightening of NPDES permits and the implementation of Best Management Practices;
2. Dredging of contaminated sediments;
3. Capping or remediation of contaminated sediments;
4. Removal of dams;
5. Construction of Water Quality Treatment/Sediment Capture Basins.

5.3.6.1 Tightening of NPDES permits and the Implementation of Best Management Practices. Refer to Section 5.3.4.1 (Control of Nutrients) for a discussion on the tightening of NPDES permits and the implementation of Best Management Practices.

5.3.6.2 Dredging of Contaminated Sediments. Dredging of contaminated sediments is similar to dredging for wetlands expansion. The reader is referred to Section 5.3.1.8 and to the side discussion on material removal.

5.3.6.3 Capping or remediation of contaminated sediments.

5.3.6.3.1 Capping. Caps that range from 6 inches of topsoil and seed or 6 inches of gravel (to eliminate some contact with contaminated sediments and volatization of contaminants) to full RCRA hazardous waste caps (including a combination of geosynthetic and natural materials) can be used to confine contaminated sediments in river bottoms, banks, and floodplains. Caps need to be designed for site-specific conditions. The Corps would examine and design caps in the feasibility stage.

5.3.6.3.2 Innovative Technologies. Innovative technologies that use heat, chemicals, electricity, biological organisms, vegetation, etc. were considered to reduce the contaminated sediments and bank materials. Due to the widespread and variable nature of the contamination, use of any of the individual technologies or a grouping of the technologies to treat the entire area was not judged to be prudent. However, the use of innovative technologies in small areas that have known high levels of contamination could be considered for further study in feasibility study efforts.

5.3.6.3.3 Soil Washing. Soil washing is a physical process in which the larger, uncontaminated particles are removed from dredge materials and reused rather than put into a disposal area. It makes use of two general principles: 1. Large soil particles, that are spherical in shape, settle out of water faster than small ones, if they have equal densities; 2. Contaminants have a greater affinity to small soil particles than large particles. Typically, a sluiceway structure that empties into a settling basin is used to implement soil washing. Slurries that contain the dredge materials are pumped down the sluiceway. When the slurry velocity decreases near the end of the sluiceway, the larger particles settle out of the water column. Periodically the pumping is stopped and the larger particles are removed from the sluiceway. The smaller contaminated particles are retained in the settling basin. Soil washing will be considered in future development of the proposed projects at Fisherville Pond Dam and Singing Dam.

5.3.6.4 Removal of dams. Refer to Sections 5.3.3.1 and 5.3.5.1 for a discussion on the removal of dams. Removing a dam would have some positive, and some negative water quality aspects.

5.3.6.5 Construction of Water Quality Treatment/Sediment Capture Basins. The construction of water quality/sediment capture basins has already been described as a solution to the loss and degradation of lake and pond habitat. The reader is referred to Sections 5.3.4.1 and 5.3.4.4 for a more complete discussion.

VI. DESCRIPTION OF PROTOTYPE RESTORATION PROJECTS

The projects discussed in this section indicate several of the types of actions that could be performed by the Corps to address the ecological problems in the watershed. They do not necessarily indicate the specific projects that would be selected after detailed examination performed in the Feasibility Phase. Not all types of projects that the Corps could implement have been illustrated as prototype projects, e.g. small dam removal. Project descriptions have been kept brief, with design assumptions and operations and maintenance requirements largely omitted since the intent of the descriptions is only to present the types and costs of actions that the Corps could perform. Formulation of specific actions and preliminary design of the selected projects would take place during the Feasibility Study.

Table 13 presents a summary of the cost estimates for the selected restoration projects. All cost estimates, except for the fish passage facilities, were prepared using the Corps MCACES cost estimating software. The cost estimates reflect 1997 price levels and include a 20 percent contingency factor and escalation to the mid point of construction. Cost estimates for the fish passage facilities were prepared by the USFWS and include a 15 percent contingency factor. Estimates for engineering & design, construction management, real estate, and operations and maintenance (O&M) for each of the projects are also presented. The present worth of O & M costs were calculated based on a project life of 50 years and a Federal interest rate of 7.375%. Appendix E provides a breakdown of costs for each of the prototype restoration projects.

6.1 Fisherville Pond

6.1.1 Site Description

Fisherville Pond is located on the Blackstone River at its confluence with the Quinsigamond River in Grafton, Massachusetts. Figure 5 indicates its location relative to several other dams on the Blackstone River. Aerial photographs of the site are provided in Appendix E. The 145 acre impoundment is maintained by Fisherville Dam, a 10 foot high, 650-foot long earthen dam with a 200-foot long stone spillway constructed in 1882. The pond was drained in 1982 to facilitate the dredging of gravel and removal of aquatic vegetation from the northern (Quinsigamond River) portion of the pond. Due to questions raised by MADEM's Office of Dam Safety regarding the safety of the dam, the owner chose to weld the outlet gate open in 1986 to keep the pond drained. However, the outlet has subsequently become plugged with debris and

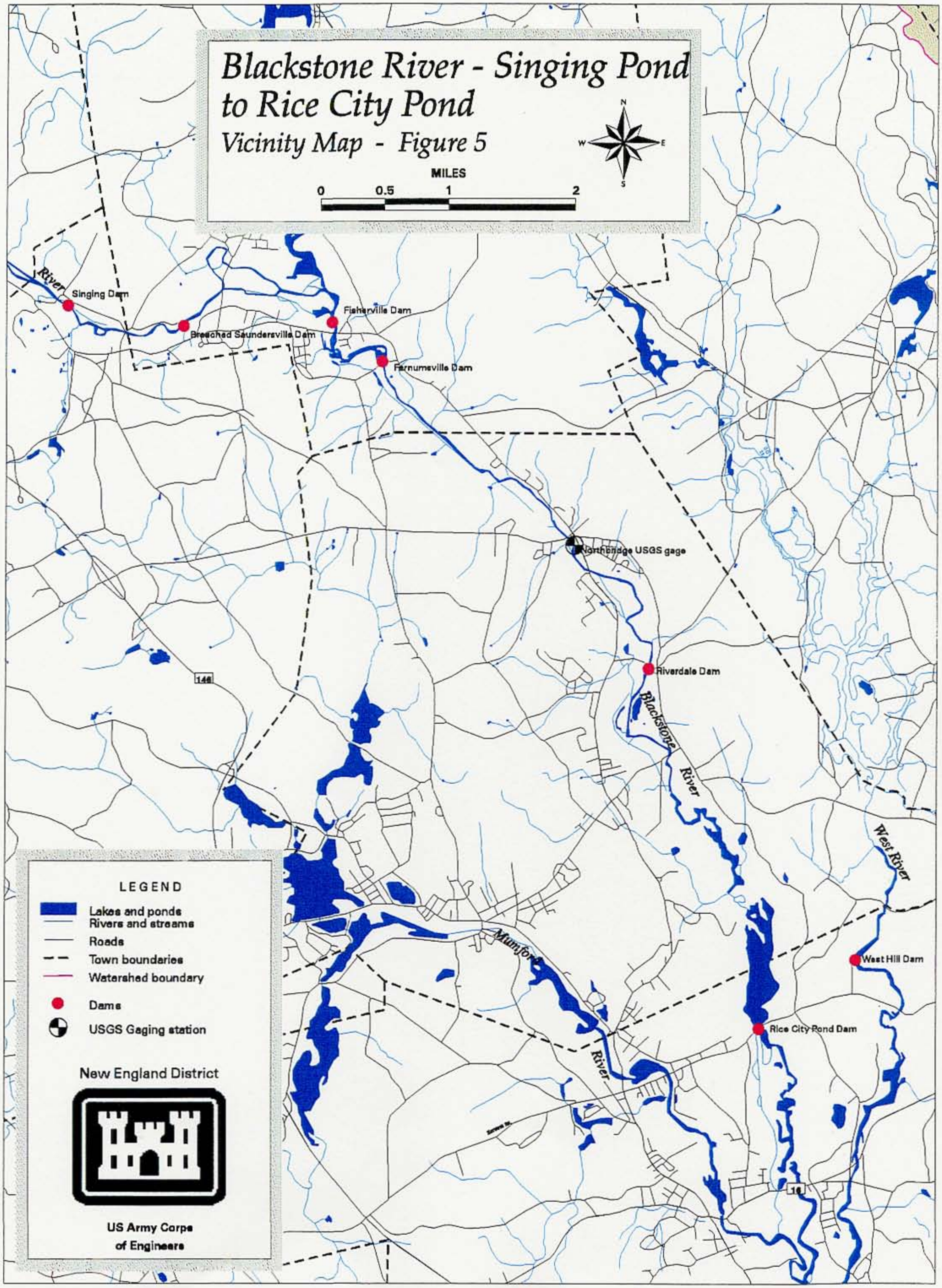
Table 13 Costs of Prototype Restoration Projects						
Restoration Project	**Construction Cost [1]**	**Engineering & Design**	**Construction Management**	**Real Estate Cost**	**Present Worth O&M Costs**	**Total Project Cost**
Fisherville Alternative 1	$778,000	$47,000	$50,000	$140,000	$89,000	$1,100,000
Fisherville Alternative 2A	$1,680,000	$101,000	$107,000	$140,000	$89,000	$2,120,000
Fisherville Alternative 2B	$2,960,000	$178,000	$188,000	$140,000	$89,000	$3,560,000
Fisherville Alternative 2C	$5,940,000	$356,000	$378,000	$140,000	$89,000	$6,900,000
Lonsdale Drive-In Alternative 1	$1,300,000	$78,000	$83,000	$615,000[2]	$21,000	$2,100,000
Lonsdale Drive-In Alternative 2	$546,000	$33,000	$35,000	$615,000	$21,000	$1,250,000
Former Rockdale Pond	$1,480,000	$89,000	$94,000	$45,000	$21,000	$1,730,000
Singing Dam Sediment Capture Pond	$2,590,000	$155,000	$164,000	$20,000	$91,000	$3,020,000
Beaver Brook Daylighting	$2,440,000	$146,000	$155,000	$21,000	$21,000	$2,780,000
Riverdale Gravel Pit Wetlands Restoration	$482,000	$29,000	$31,000	$18,000	$21,000	$581,000
Rice City Pond Dam Raising	$3,970,000	$238,000	$253,000	$32,000	$86,000	$4,580,000
Fish Passage Facilities at 4 Dams	$1,760,000	$221,000	$220,000	[3]	$148,000[4]	$2,350,000

1 Construction costs include contingencies and escalation.

2 The estimate real estate cost for the Lonsdale Drive-In site is based on generalized information and is not site specific. The State of Rhode Island is currently conducting an appraisal which will provide a more accurate estimate of the property value.

3 Real estate values for the lower four dams were not calculated as part of the Reconnaissance investigation.

4 This includes $23,000 for normal O&M plus $125,000 for a monitoring program.


Blackstone River - Singing Pond to Rice City Pond
Vicinity Map - Figure 5
N
W
E
S
MILES
0
0.5
1
2
River
Singing Dam
Breached Saundersville Dam
Fisherville Dam
Farnumsville Dam
Northbridge USGS gage
Riverdale Dam
Blackstone
River
146
West River
West Hill Dam
Mumford
River
Rice City Pond Dam
16
LEGEND
Lakes and ponds
Rivers and streams
Roads
Town boundaries
Watershed boundary
Dams
USGS Gaging station
New England District
US Army Corps of Engineers

the pond has been at normal levels, with water flowing over the spillway, for at least the last three years.

Fisherville Pond currently provides about 45 acres of shallow open water habitat and about 100 acres of emergent, wet meadow, and scrub-shrub wetland habitat (see attached photographs). Emergent wetland is dominated primarily by cattail. Woolgrass, sedges, Bidens sp., purple loosestrife, *Phragmites*, reed canary grass, and other grasses are predominant in wet meadow areas. Based on a review of old aerial photographs, most of the wet meadow and emergent habitat developed from shallow open water areas between 1938 and 1952.

Historically, Fisherville Pond was one of the premier waterfowl habitat areas in central Massachusetts. Prior to the pond's draining, a 4.5 acre area north of the Blackstone River channel and a 4.6 acre area north of the dam provided exceptional habitat for migrating black duck, mallard, and other waterfowl. Both areas consisted of shallow (< 3 feet) open water habitat interspersed with stands of cattail, pickerelweed, and other emergents. The emergent vegetation died during the drawdown and has not recolonized the area after restoration of normal water levels, probably due to lack of suitable mudflat conditions to promote seed germination. According to MADFW[5], the loss of emergent vegetation in the two areas reduced the habitat value of the pond for waterfowl by 80 percent.

Fish surveys conducted by the MADFW in 1992 and the Corps in 1996 found that the pond supports a moderately diverse and abundant warm water fish community. Although the community is dominated by pollution tolerant species (white sucker, golden shiner, and carp), good numbers of less pollutant tolerant species such as largemouth bass, yellow perch, and bluegill sunfish are also present.

Fisherville Pond sediments are contaminated with copper, chromium, lead, cadmium, and other metals. A preliminary baseline ecological risk characterization conducted for this study concluded that sediment contamination probably does not pose a significant risk to waterfowl, but may pose a risk to benthic invertebrates and fish. This analysis utilized existing bulk sediment chemistry data, biotoxicity testing conducted by the EPA, fish tissue analysis for metals and PCBs conducted by the MADFW, and Acid Volatile Sulfides/Soluble Extractable Metals data collected by the Corps.

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5 H W Heusmann, MADFW Waterfowl Project Leader

Fisherville Pond has considerable recreational value to the local community. Access is provided by a boat ramp at the gravel pit. The area is also frequently used by fishermen and by duck hunters during the fall. Canoeists find the portage between Fisherville Pond and the Blackstone River south of the dam difficult due to lack of landings. Open land east of the pond and the power line corridor is used by off road vehicles.

6.1.2 Project Description

Two alternatives to restore and enhance waterfowl habitat at Fisherville Pond were developed. Alternative 1 (see Figure 6) would involve stabilization of the earthen dam in its existing configuration[6], reconstruction of the outlet to control pond water levels, construction of approximately 2 acres of potholes within wet meadow areas, and the establishment of a 200-foot vegetated riparian buffer along the eastern side of the pond. Revegetation of degraded waterfowl habitat areas would be accomplished by maintaining shallow (mudflat) conditions during the growing season to promote germination of the existing seedbank. Once vegetation is well established, normal water levels (spillway crest) would be maintained. The estimated total cost of this alternative is approximately $1,100,000.

Alternative 2 (see Figure 7) consists of the project features described above combined with the dredging of about 25 acres of wet meadow to provide additional open water and emergent habitat. Waterfowl and fisheries habitat would be restored by creating a mosaic of shallow emergent marsh and open water habitat. The restored area would be a mixture of roughly 50 percent emergent vegetation and 50 percent open water. Final depths of 18-30 inches would be attained for approximately half of the area, with the remainder of the dredged area having an average depth of 4 feet and maximum depth of 6 feet. The area would be revegetated by plantings and natural recolonization. Studies would be conducted to determine if sediment exposed by dredging would pose an unacceptable risk to waterfowl, invertebrates or fish. If necessary, the area would require overdredging and capping with clean material.

Alternative 2 was further subdivided into three sub-alternatives to present a range of estimated costs which include various project features that may be required if future studies

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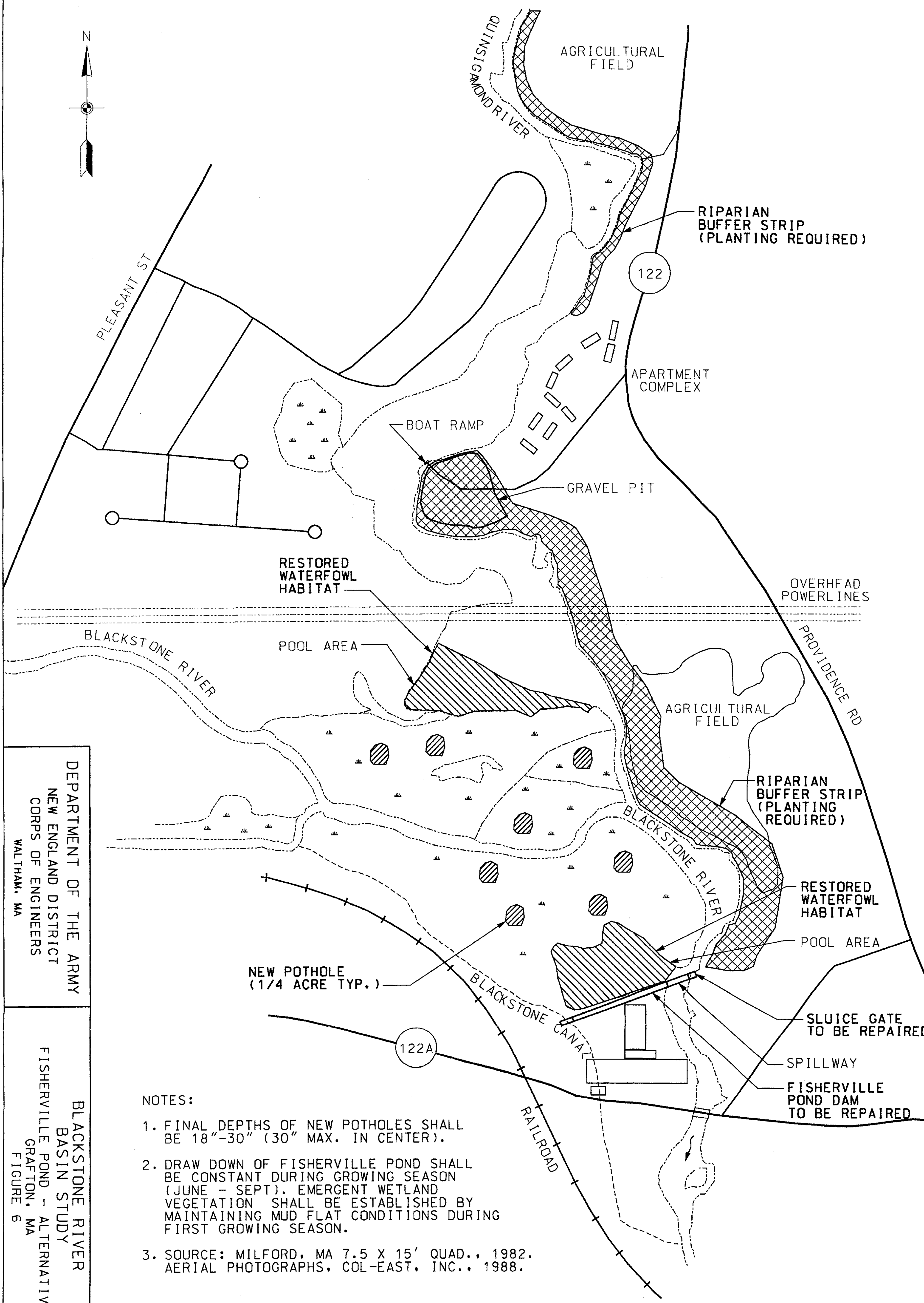
6 This assumes the receipt of a waiver from MADEM Office of Dam Safety to retain the existing spillway size.



NOTES:

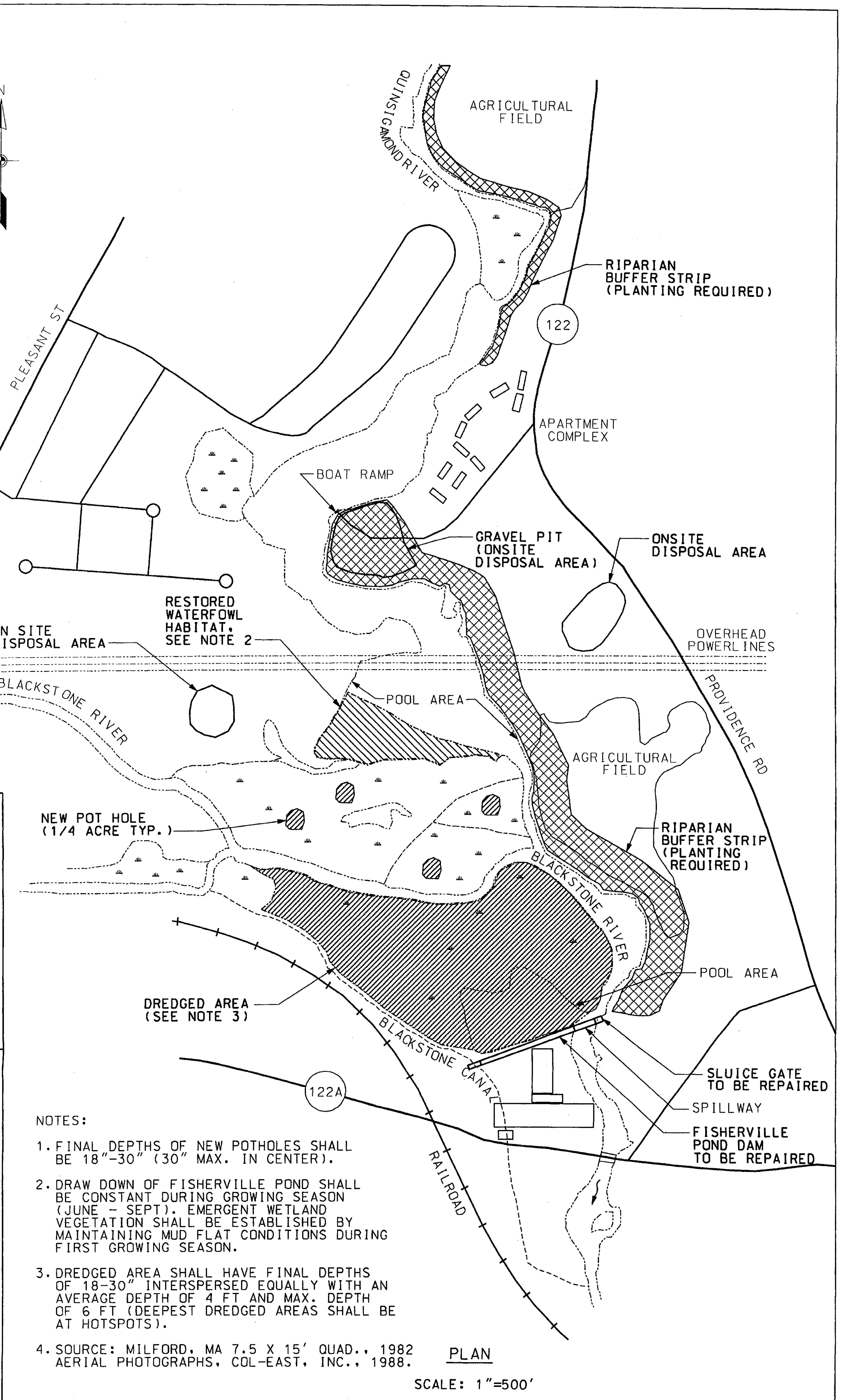
1. FINAL DEPTHS OF NEW POTHOLES SHALL BE 18"-30" (30" MAX. IN CENTER).
2. DRAW DOWN OF FISHERVILLE POND SHALL BE CONSTANT DURING GROWING SEASON (JUNE - SEPT). EMERGENT WETLAND VEGETATION SHALL BE ESTABLISHED BY MAINTAINING MUD FLAT CONDITIONS DURING FIRST GROWING SEASON.
3. SOURCE: MILFORD, MA 7.5 X 15' QUAD., 1982. AERIAL PHOTOGRAPHS, COL-EAST, INC., 1988.

PLAN

SCALE: 1"=500'

DEPARTMENT OF THE ARMY
NEW ENGLAND DISTRICT
CORPS OF ENGINEERS
WALTHAM, MA

BLACKSTONE RIVER
BASIN STUDY
FISHERVILLE POND - ALTERNATIVE 1
GRAFTON, MA
FIGURE 6



NOTES:

1. FINAL DEPTHS OF NEW POTHOLES SHALL BE 18"-30" (30" MAX. IN CENTER).
2. DRAW DOWN OF FISHERVILLE POND SHALL BE CONSTANT DURING GROWING SEASON (JUNE - SEPT). EMERGENT WETLAND VEGETATION SHALL BE ESTABLISHED BY MAINTAINING MUD FLAT CONDITIONS DURING FIRST GROWING SEASON.
3. DREDGED AREA SHALL HAVE FINAL DEPTHS OF 18-30" INTERSPERSED EQUALLY WITH AN AVERAGE DEPTH OF 4 FT AND MAX. DEPTH OF 6 FT (DEEPEST DREDGED AREAS SHALL BE AT HOTSPOTS).
4. SOURCE: MILFORD, MA 7.5 X 15' QUAD., 1982 AERIAL PHOTOGRAPHS, COL-EAST, INC., 1988.

PLAN

SCALE: 1"=500'

DEPARTMENT OF THE ARMY
NEW ENGLAND DISTRICT
CORPS OF ENGINEERS
WALTHAM, MA

BLACKSTONE RIVER
BASIN STUDY
FISHERVILLE POND - ALTERNATIVE 2
GRAFTON, MA
FIGURE 7

determine that the contaminated sediments pose a risk to the habitat area. Alternative 2A is without capping, Alternative 2B includes a 1 foot topsoil cap, while alternative 2C includes a 2-foot gravel cap with another foot of topsoil placed on top of the gravel. Total costs are estimated at $2,120,000 for alternative 2A, $3,560,000 for alternative 2B, and $6,900,000 for Alternative 2C.

Both of the alternatives for Fisherville Pond provide additional waterfowl breeding habitat (potholes) and valuable staging habitat for migrating mallard, black duck, wood duck, and other waterfowl. Chain pickerel, largemouth bass, and many other fish species would also benefit from restoration of open water/emergent habitat. Dredging (Alternative 2) would enhance benthic and fish communities if underlying sediment is less contaminated than surficial sediment. Repairs to the dam would reduce the risk of dam failure and loss of existing and improved resources at Fisherville Pond, and potential impacts to downstream habitat caused by washout of contaminated sediment from the impoundment.

The following additional actions have been suggested at the Fisherville Pond site to provide added benefits. One major action would be the dredging of sediment contamination "hot spots" or selected areas along the watered channel where an increased water depth is desired. Sinuosity could be added to the channel in order to increase water contact time for nutrient removal. Provision of fish passage, canoe portage facilities, and interpretive features may also be considered in addition to the alternatives described above. The Blackstone canal could be reactivated for canoe passage. This would likely entail "daylighting" of the portion of the canal now under the mill and road (state route 122A) downstream of the dam. These project features will be investigated in more detail during future studies.

6.2 Lonsdale Drive-In

6.2.1 Site Description

The Lonsdale Drive-In is a 41 acre site located along the Blackstone River in Lincoln, Rhode Island. Photographs of the site are provided in Appendix E. The site is a broad floodplain terrace that was developed as an outdoor drive-in theater in the early 1950's. Prior to construction of the theater, the site provided wet meadow and grassland habitat and, for many years, was used as a pasture. During construction of the drive-in, about 22 acres of the site was bituminous concrete underlain with gravel bedding. Top soil was removed prior to paving. There is no evidence that waste material was disposed on site. The state of Rhode Island and EPA are negotiating with the current owner (Macklands Inc.) to purchase the site with funds from a settlement at the Landfill & Resource Recovery Superfund Site in North Smithfield, RI. Once acquired by the State, the site will be immediately available for restoration.

Deteriorated paved areas of the drive-in are currently sparsely vegetated with grasses, shrubs, and small trees, and provide little habitat value. Vegetation is more abundant in the lower terrace, probably due to greater deposition of riverine sediment in this area. Several acres of the site are currently forested. Forested areas include a narrow fringe of riparian habitat along the river and a steep embankment between the drive-in and Route 122.

6.2.2 Project Description

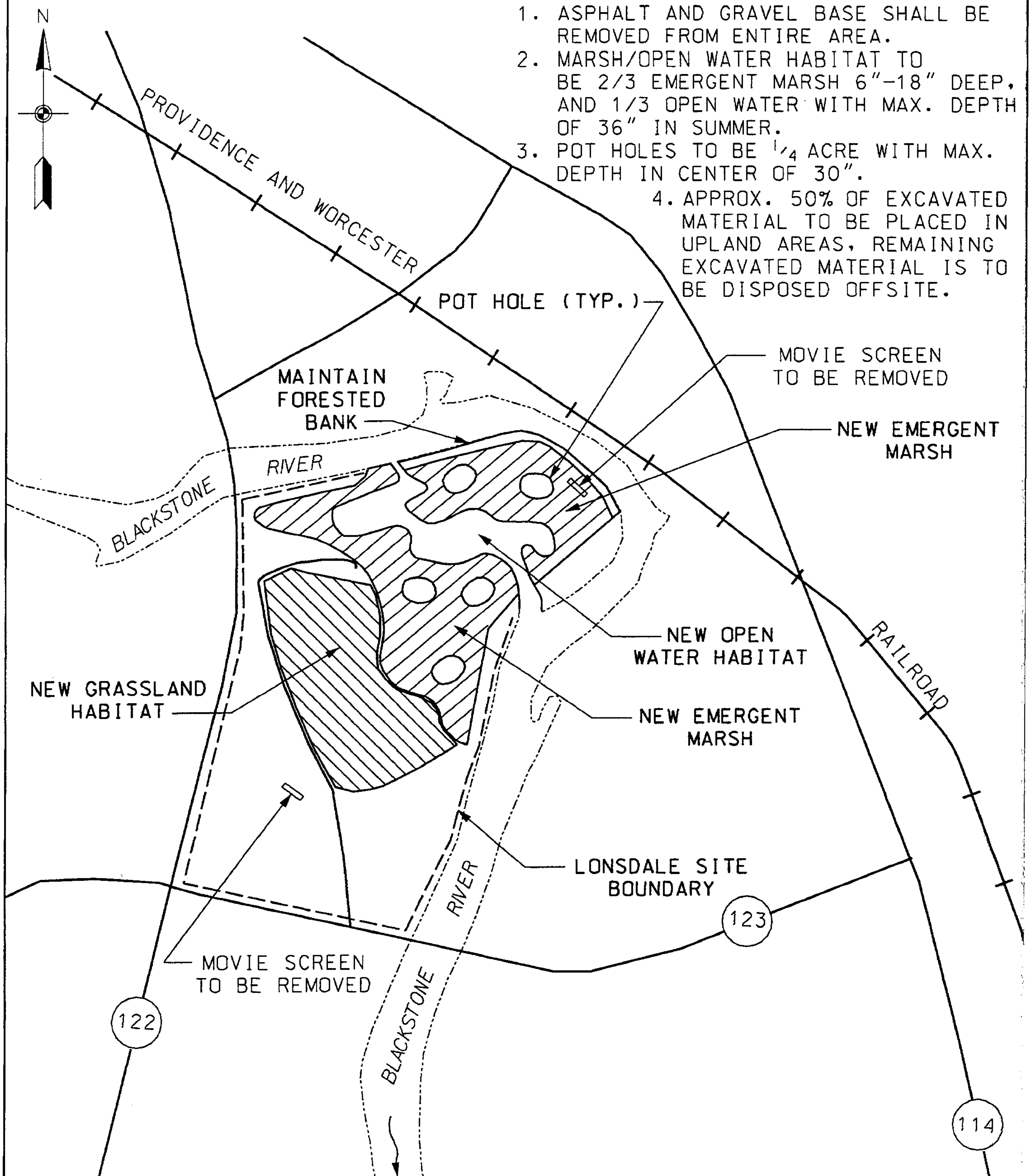
Two alternatives to restore and enhance fisheries and waterfowl habitat at the Lonsdale site were developed. Alternative 1 (see Figure 8) involves the removal of the asphalt and gravel base of the former drive-in to create about 15 acres of emergent marsh and open water habitat. Average excavation depth would be about 7 feet. Existing forested riparian habitat along the river would be preserved as much as possible. The main open water area would be a broad channel connected to the Blackstone River. The channel would have an average depth in summer of 36 inches. Several 1/4 acre potholes with a maximum depth of 30 inches would also be constructed within the emergent areas. Emergent wetland would range in depth from 6 to 18 inches. Six inches of organic rich soil would be placed in emergent wetland areas to support growth of vegetation. Approximately 1/2 of the emergent marsh area (ca. 5 acres) would be planted with emergent plants. Remaining emergent areas would be allowed to re-vegetate naturally.

In addition to wetlands, about 7 acres of the grassland habitat would be restored. Pavement would be removed, six inches of topsoil placed on top of the existing gravel bedding, and the area seeded with a mix of perennial grasses native to New England. Scattered trees and shrubs would be planted to provide shelter and nesting habitat for songbirds. The estimated total cost of this alternative is approximately $2,100,000.

Alternative 2 (see Figure 9) would involve the creation of about 22 acres of grassland habitat and no wetland. Pavement would be removed, six inches of topsoil placed on top of the existing gravel bedding, and the area seeded with a mix of perennial grasses native to New England. The estimated total cost of this alternative is approximately $1,250,000.

NOTES:

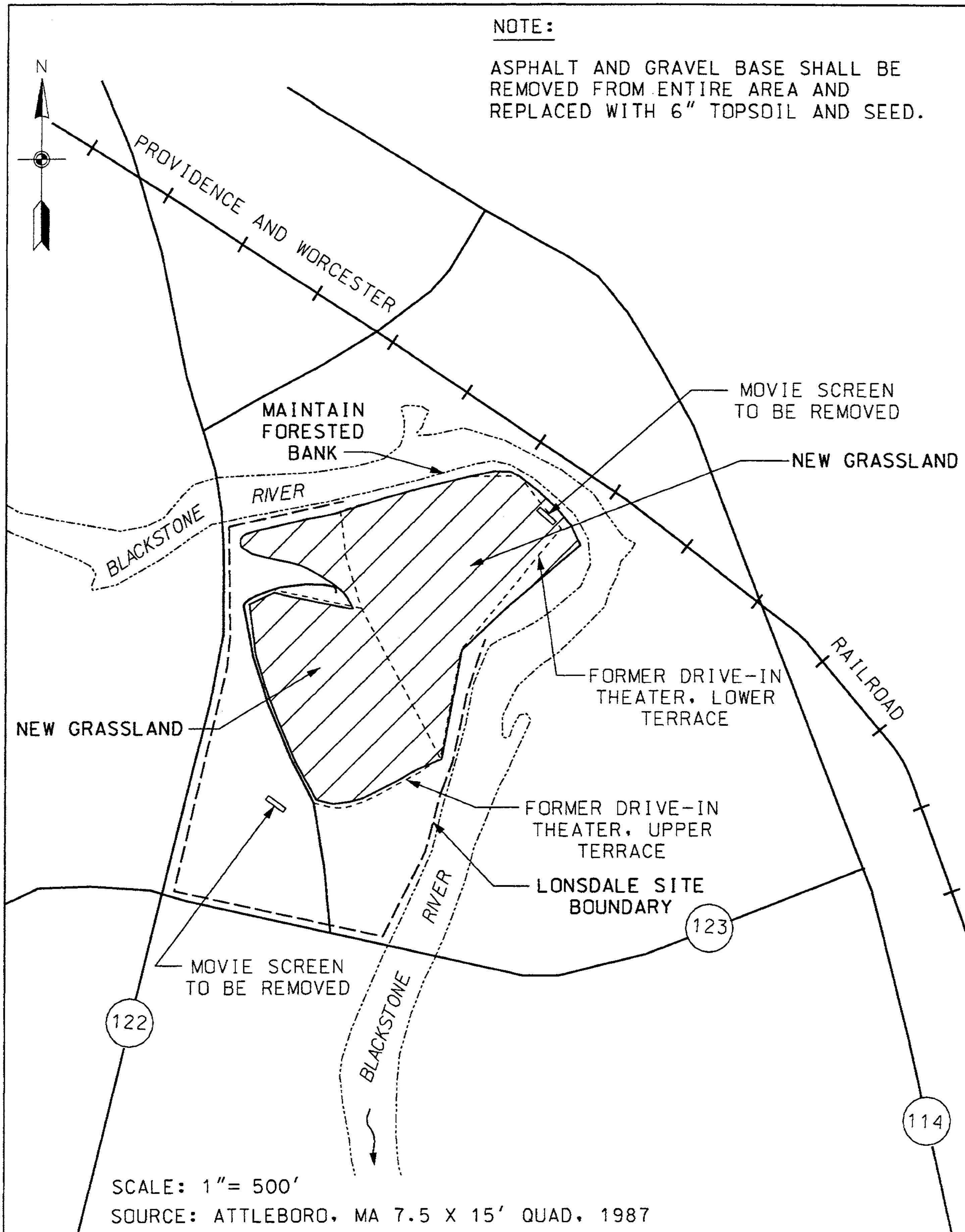
1. ASPHALT AND GRAVEL BASE SHALL BE REMOVED FROM ENTIRE AREA.
2. MARSH/OPEN WATER HABITAT TO BE 2/3 EMERGENT MARSH 6"-18" DEEP, AND 1/3 OPEN WATER WITH MAX. DEPTH OF 36" IN SUMMER.
3. POT HOLES TO BE 1/4 ACRE WITH MAX. DEPTH IN CENTER OF 30".
4. APPROX. 50% OF EXCAVATED MATERIAL TO BE PLACED IN UPLAND AREAS, REMAINING EXCAVATED MATERIAL IS TO BE DISPOSED OFFSITE.



SCALE: 1"= 500'

SOURCE: ATTLEBORO, MA 7.5 X 15' QUAD, 1987

DEPARTMENT OF THE ARMY NEW ENGLAND DISTRICT CORPS OF ENGINEERS WALTHAM, MA	BLACKSTONE RIVER BASIN STUDY LONSDALE DRIVE-IN - ALTERNATIVE 1 LINCOLN, RI FIGURE 8



DEPARTMENT OF THE ARMY
NEW ENGLAND DISTRICT
CORPS OF ENGINEERS
WALTHAM, MA

BLACKSTONE RIVER
BASIN STUDY
LONSDALE DRIVE-IN - ALTERNATIVE 2
LINCOLN, RI
FIGURE 9

Both alternatives would include a small parking area at the Route 122 entrance to the site for recreational access, a boat ramp, a hiking trail, an educational display, and a wildlife observation platform overlooking the wetland.

Emergent wetland and open water habitat created at the site (Alternative 1) would benefit waterfowl, resident fish, and with provision of fish passage facilities at downstream dams, anadromous fisheries. Grassland restored at the site (Alternative 2) would provide habitat for small mammals, song birds, and raptors. Grassland is one of the most threatened habitat types in New England due to the ease in development of this habitat coupled with the successional expansion of forests that were previously logged.

6.3 Former Rockdale Pond (Coz Chemical) Site

6.3.1 Site Description

The former Rockdale Dam in Northbridge formed a narrow 1.2 mile long impoundment with a total surface area of about 33 acres. Aerial photographs indicate that much of the impoundment had silted in to form a shallow pool by the early 1950's. The dam was damaged by a hurricane in the 1960's and removed by its owner (Coz Chemical Corporation) in 1974 due to concerns about dam stability and the usefulness of the impoundment.

Removal of the dam re-established about one mile of free flowing riverine habitat and about 30 acres of riparian habitat located within the former impoundment. About 15 acres of riparian habitat is currently severely degraded due to poor vegetative growth. Embankments along the Blackstone River throughout much of the former impoundment are also poorly vegetated and subject to erosion.

Riparian habitat in the former impoundment is currently sparsely vegetated with grasses, herbs, and scattered small trees and shrubs. The most highly degraded areas have very little (< 10%) vegetative cover. Due to lack of vegetative cover, the area has very little wildlife habitat value. The risk that contaminated sediments on the overbank pose to wildlife and humans has not been evaluated but may be potentially significant. Poor growth of vegetation may be due to low pH (< 5), low nutrient levels, dry soils, and/or high concentrations of metals or other contaminants in the soil.

6.3.2 Project Description

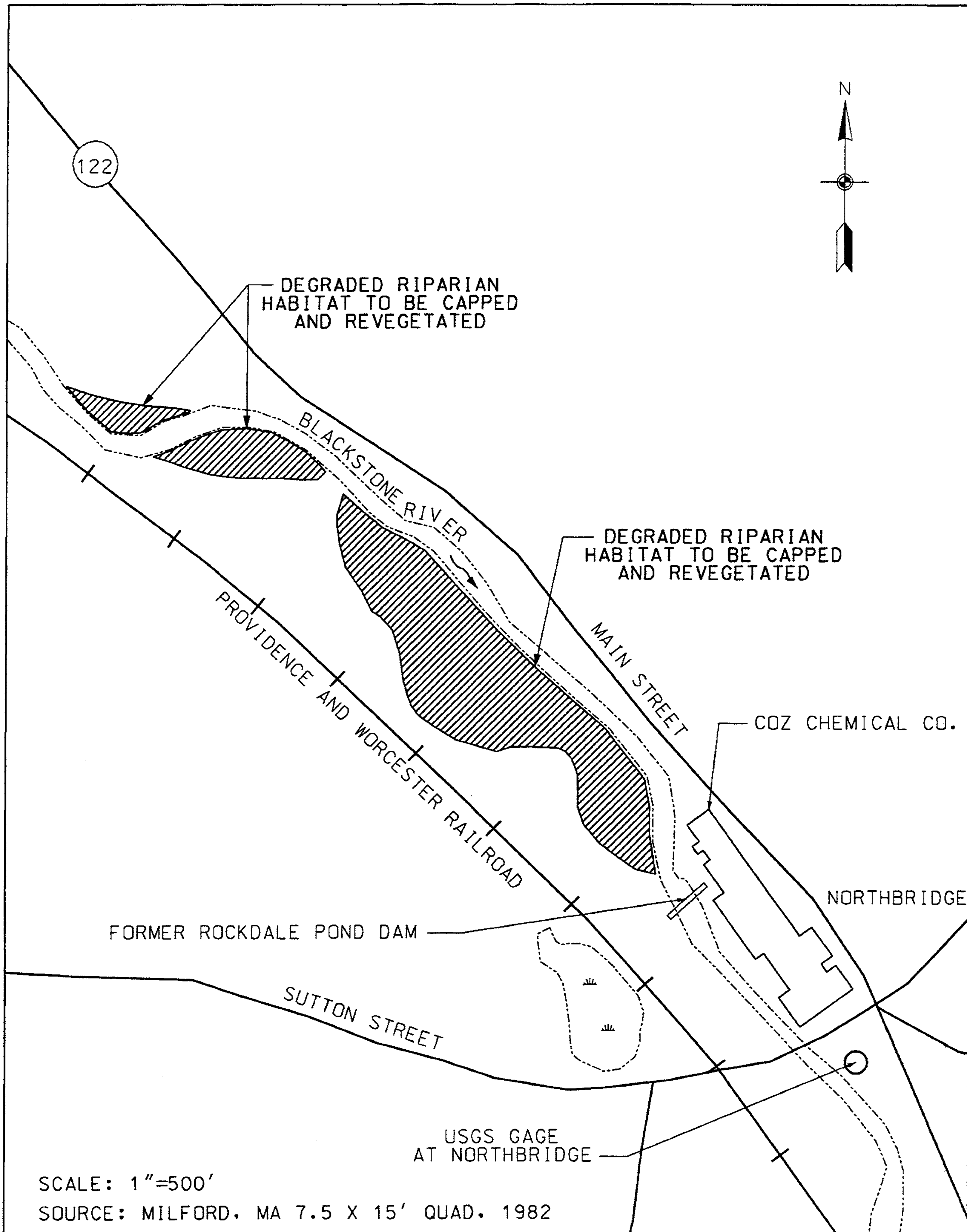
Restoration efforts will focus on stabilization of eroding embankments and revegetation of about 15 acres of the most highly degraded riparian habitat in the former impoundment (see Figure 10). Embankments will be graded to form a 2:1 slope and capped. Above the normal water level, embankments will be capped with one foot semi-impervious glacial till and one foot of topsoil. The slope will be seeded with a perennial grass mixture, stabilized with a biodegradable geotextile fabric, and planted with trees and shrubs. The toe of the embankment will be protected with one foot of gravel bedding and one foot of stone protection. The remaining highly degraded riparian habitat will be capped with one foot of semi-impervious glacial till, one foot of topsoil, and seeded with a conservation mix. About one-half the area would be planted with trees and shrubs to speed development of forested riparian habitat. The remainder will provide grassland habitat. A planting plan will be developed during the design phase. The estimated total cost of this alternative is approximately $1,730,000.

The proposed plan would stabilize eroding embankments and restore about 15 acres of degraded riparian habitat. Stabilization of embankments and capping of degraded riparian habitat will eliminate loading of contaminated sediment into the river. Ecological and human health risk due to exposure to contaminated sediment will be greatly reduced. Grassland restored at the site would provide habitat for small mammals, song birds, and raptors. Wooded riparian areas would eventually provide habitat for many wildlife species. Any risk posed to wildlife from contact with contaminated sediment or food chain exposure will be greatly reduced. Shade provided by trees and shrubs close to the river would moderate stream temperatures. Leaf fall from woody vegetation would support the aquatic food chain.

6.4 Singing Dam Sediment Capture Pond

6.4.1 Site Description

Singing Dam is located on the Blackstone River in the town of Sutton, several miles upstream of Fisherville Pond. The dam is a 100 foot long, 10 foot high granite block overflow structure without a sluiceway or other water control structure . Much of the original impoundment is filled in with soft sediment. Open water is largely limited to a shallow (< 4" deep) 80 - 100 foot wide backwater channel which extends about 2000 feet upstream. The



DEPARTMENT OF THE ARMY NEW ENGLAND DISTRICT CORPS OF ENGINEERS WALTHAM, MA	BLACKSTONE RIVER BASIN STUDY FORMER ROCKDALE POND NORTHBRIDGE, MA FIGURE 10

impoundment includes a large emergent marsh south of the channel and a large island located near the head of the impoundment. The channel along the southern side of the island is silted in and heavily vegetated. Sediments in the marsh have high levels of lead, copper, chromium, zinc, nickel, and arsenic.

No information is available about fisheries resources in the impoundment. Shallow water in the channel and poor water quality, however, is likely to severely limit development of warmwater fisheries according to MADFW (Lee McLaughlin). Toxicity testing indicates that the benthic habitat quality above Singing Dam is poor. Emergent marsh south of the channel provides good waterfowl habitat.

6.4.2 Project Description

A project is proposed at this site primarily for the purpose of protecting investments made and ecological improvements obtained at downstream sites. Approximately 73,000 cubic yards of sediment will be dredged from a 2,700 foot reach of the channel (see Figure 11). The channel will be dredged to an average depth of about 8 feet. Dredging will be accomplished either by a small hydraulic dredge or by draining the impoundment and using conventional excavating equipment. The material will be dewatered on-site at a confined dewatering area and disposed off-site. The material should be suitable for use as cover at a solid waste landfill if, as expected, it does not fail Toxicity Characteristic Leaching Procedure (TCLP) tests that are used to determine if a waste must be disposed of as a hazardous waste. If the material does fail TCLP tests, however, project costs are likely to be prohibitively expensive and the project is unlikely to be cost effectiveness. An additional 47,000 cubic yards of material will be excavated from an upland area situated near the power line crossing. This will increase the size of the sediment capture impoundment, improving capture efficiency. Hydrologic and hydraulic studies performed in the feasibility study will determine sediment capture ratios or grain sizes captured. Material excavated from the upland area would likely be suitable for use as landfill cover. The estimated total cost of this alternative is approximately $3,020,000.

Depending on effectiveness of upstream sediment control measures, the impoundment would require maintenance dredging every 5 to 10 years. As the emergent marsh south of the channel gradually fills in, it will be beneficial to eventually dredge a portion of this area to improve waterfowl habitat quality.

Dredging of the impoundment will greatly increase its ability to trap significant amounts of sediment and other pollutants during wet weather events and secondarily restore open water fisheries habitat. Removal of sediment at Singing Dam will, over the long-term (ie. several decades) protect valuable fisheries and wildlife habitat at Fisherville Pond and at other downstream sites.

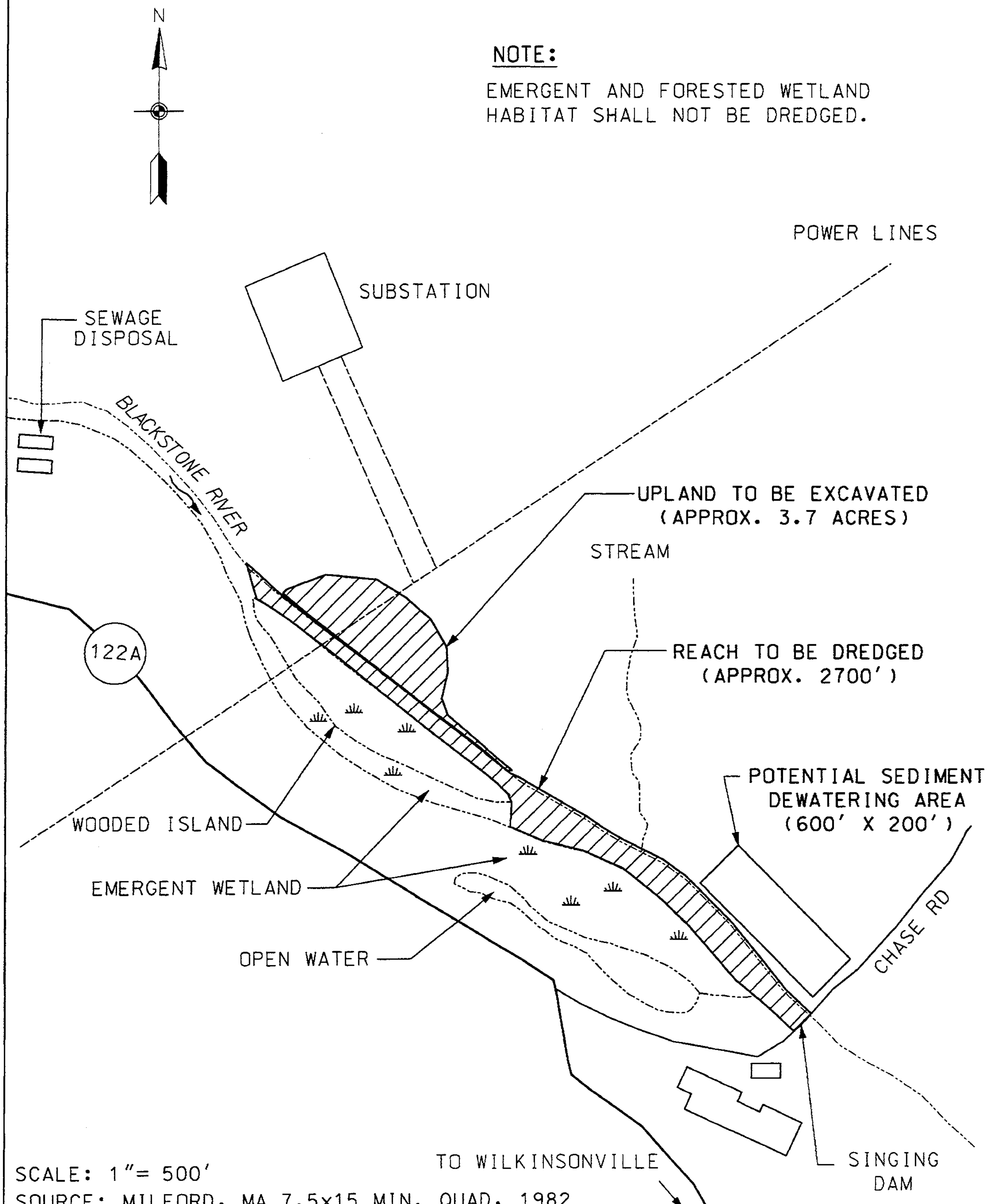
6.5 Daylighting of Beaver Brook

6.5.1 Site Description

Beaver Brook is a small urban stream located in Worcester, Massachusetts. The brook originates in relatively undeveloped low density residential neighborhoods and flows in a southerly direction through heavily developed residential and commercial areas before joining the Middle River in Webster Square. Much of the flow to the brook is carried by an extensive storm drainage system.

Two local organizations, the Massachusetts Audubon Society and the Blackstone Headwaters Coalition, have been exploring the possibility of daylighting a 3500 foot reach of the brook between Maywood Street and Chandler Street. The reach was channelized in 1917 and covered over in the 1950's due to odor and aesthetic concerns. The Corps chose to investigate Beaver Brook in order to demonstrate a type of environmental restoration project that could be implemented in the middle of a highly urbanized environment.

Beaver Brook Park, located immediately south of Chandler Street, is an intensely developed recreational area with a variety of facilities including a baseball field, outdoor skating rink, and basketball courts. The Beaver Brook conduit passes under a grassy area along the western edge of the park. From the park downstream to May Street, the brook passes under a wooded area adjacent to a large asphalt parking lot to the east and a residential neighborhood to the west. From May Street downstream to Maywood Street, the conduit passes through a residential area. Land along the conduit is vegetated with scattered trees and shrubs, forming a long linear greenway.



DEPARTMENT OF THE ARMY NEW ENGLAND DISTRICT CORPS OF ENGINEERS WALTHAM, MA	BLACKSTONE RIVER BASIN STUDY SINGING DAM SUTTON, MA FIGURE 11

6.5.2 Project Description

Conceptual plans for restoration of Beaver Brook between Chandler Street and Maywood Street are shown on Figures 12 and 13. Daylighting of the brook may not be practicable above Chandler Street since it runs underneath an athletic field and stadium complex. Below Maywood Street the brook flows in a channelized reach that may benefit ecologically if appropriate stream restoration techniques are implemented. The existing culverted channel in the 3500 foot reach proposed to be daylighted will be replaced by a 16 foot wide open channel. Side slopes and a 50 foot wide riparian corridor would be vegetated with shrubs and trees. Boulders and deflectors would be added to provide instream habitat for fish. A system of small ponds and marsh would be constructed to improve water quality and provide additional fish and wildlife habitat. About 2 acres of the parking lot near the ponds will be restored to provide additional green space. The estimated total cost of this alternative is approximately $2,780,000.

The proposed plan will restore (daylight) about 3500 feet of stream habitat. The restored stream, riparian greenway, and ponds would greatly improve the aesthetics of the area. The pond and marsh system would improve water quality and provide a small urban recreational fishery and perhaps urban environmental education programs. However, concerns will still have to addressed relative to odor and other water quality problems possibly caused by cross connections or combined sewer overflows. Hydraulic issues associated with daylighting the river will also need to be addressed, particularly since the area is within an identified 100-year floodplain.

6.6 Restoration of Riverdale Gravel Pit

6.6.1 Site Description

The Riverdale gravel pit is located on the Blackstone River in Northbridge, Massachusetts about 1/4 mile downstream of the Riverdale Dam. About 30 acres were disturbed by the former mining operation. The site currently includes a 7 acre pond adjacent to the Blackstone River, about 15 acres of very poorly vegetated riparian habitat, several acres of emergent and scrub-shrub wetland, some early successional upland shrub habitat, and a small pond. The large pond is connected to the Blackstone during high flows by a small channel at its northern end.

Much of the large pond near the Blackstone River is greater than 5 feet deep. Emergent vegetation is limited to a very narrow fringe along the shoreline. Riparian habitat immediately east and northeast of the pond is very poorly vegetated with scattered grasses, herbs, and a few shrubs. The substrate consists of sandy gravel with some cobble.

6.6.2 Project Description

An average of about 3 to 4 feet of material will be excavated from about 12 acres of degraded riparian habitat near the large pond to create shallow water emergent/open water habitat (see Figure 14). Some of the excavated material will be disposed on site within a portion of the deep water pond. The remaining material will be consolidated in adjacent degraded riparian habit to form a low hill, capped with topsoil, and seeded with a native grass and wildflowers.

The newly created wetland will be about 50 percent emergent marsh and 50 percent open water. Areas designated as marsh will be capped with 6 inches of organic rich soil and planted with emergent vegetation. Small channels will link the northern and southern ends of the pond to the Blackstone River during high flow periods. During normal summer flows the pond will be isolated from the river. A few deep water channels would link the pond and emergent marsh/shallow open water habitat. The estimated total cost of this alternative is approximately $581,000.

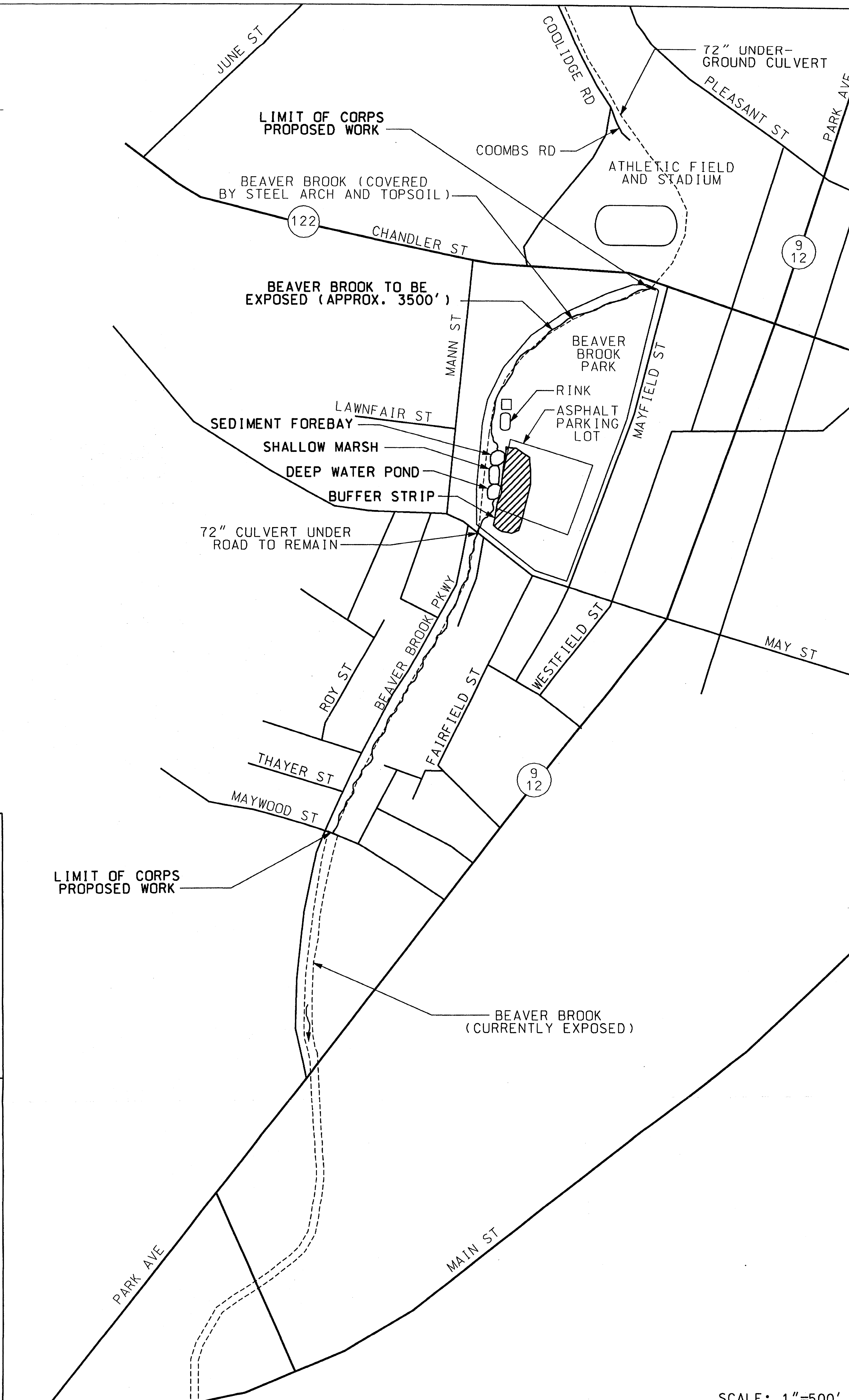
Open water and emergent habitat in the marshes and adjacent upland would provide nesting and brood habitat for mallard, American black duck, and wood duck. The wetland would also provide habitat for migrating waterfowl. The open water habitat and emergent wetland would provide nursery habitat for resident warmwater fish species such as sunfish, largemouth bass, and chain pickerel.

6.7 Raising of Rice City Pond

6.7.1 Site Description

Rice City Pond Dam is classified as a large, high hazard dam according to the Massachusetts Office of Dam Safety. It is approximately 960 feet long, including appurtenant structures, and has a maximum height of 21 feet. It is in fair condition overall.

The dam alignment extends from east to west with two ninety degree turns in it. It consists of (from east to west): an east to west earth embankment that includes a central service



SCALE: 1"=500'

SOURCE: WORCESTER NORTH, MA 7.5 X 15' QUAD, 1983

DEPARTMENT OF THE ARMY
NEW ENGLAND DISTRICT
CORPS OF ENGINEERS
WALTHAM, MA

BLACKSTONE RIVER BASIN STUDY
BEAVER BROOK
WORCESTER, MA
FIGURE 12

spillway, a north to south earth embankment that has a secondary spillway at the south end and an east to west earth embankment that includes a central diversion gate structure for the Blackstone Canal. The earth embankments have a significant amount of brush, small to large trees, grass, erosion channels and rodent holes in them. They are in fair to poor condition. The spillway structures and attached retaining walls are constructed of granite blocks, concrete and mortar. The service spillway is missing several blocks and flash boards. It appears to be in poor condition. The secondary spillway appears to be intact and in good condition. The diversion gate structure is constructed of granite blocks, concrete and mortar and is in fair to good condition. The two wood slide gates in the diversion gate structure are in poor condition and appear to be inoperable.

The spillways at Rice City Pond Dam do not meet the Massachusetts 302 CMR 10.00 requirement that they be capable of passing one-half of the probable maximum flood. The Corps would require a waiver from the MADEM Office of Dam Safety to retain the existing spillway capacity and repair the dam possibly at a lower cost than constructing an entirely new dam. However, the implications of raising the pool elevation by several feet should be assessed in terms of safety to downstream residents, particularly as this is a high hazard dam with significant storage. The proposed modifications discussed below would safely allow for raising and maintaining the pool at an elevation five feet higher if at least three feet of freeboard (the elevation distance from the water surface to the top of the dam) is maintained.

6.7.2 Project Description

Continuous rains following Hurricane Diane (August 1955) resulted in the failure of this dam. The dam was reconstructed in 1957, although spillway heights were lowered approximately five feet due to concerns of another dam failure. Purpose of the proposed project would primarily be to significantly expand wetlands and waterfowl habitat on the mainstem Blackstone River by raising the pool to its former higher level. A major secondary benefit of raising the pool would be the permanent submergence of the sediments, 80 percent of which are currently exposed during low flows (MADEM).

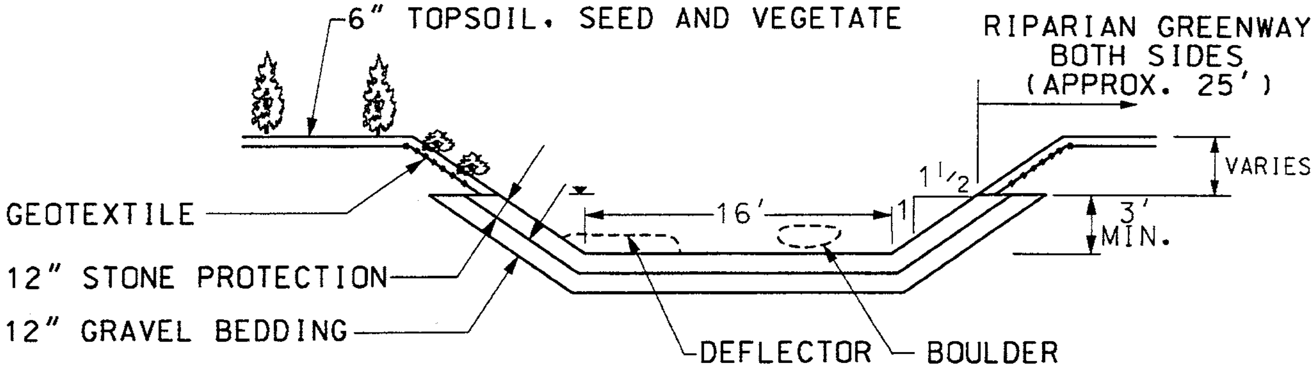
The proposed modifications require that the upstream and downstream slopes of the dam be cleared, grubbed, reshaped and resurfaced, the two spillways be raised five feet and a cut-off be constructed along the centerline of the dam. A topsoil and seed surface underlain by compacted gravel is proposed on the reshaped downstream slope. A stone protection surface underlain by gravel bedding and compacted gravel is proposed on the reshaped upstream slope. The two raised spillways and their adjacent retaining walls would be constructed of reinforced concrete. A proposed sheet pile cut-off 50 feet in depth is initially judged to be sufficient. An additional seepage study would be required to confirm the type of cut-off and depth. The modifications would allow the pool to be raised five feet so greater environmental qualities would be attained in and around the upstream pool but would not prevent overtopping of the dam if a large storm event were to occur. The estimated total cost of this alternative is approximately $4,580,000. No attempt at estimating the cost of completely rebuilding the dam has been made. Further investigations may, however, indicate the need for raising the embankment of the dam in order to insure that adequate freeboard is maintained.

Raising of Rice City Pond would negatively impact the canal towpath and lock. However, the gravel surface of the original towpath is currently buried under approximately 2 feet of silt. Raising the dam would result in an increased hydraulic retention time. This could result in settling of suspended solids, and a decrease in dissolved oxygen.

6.8 Fish Passage Facilities at the Four Most Downstream Dams (Phase 1)

6.8.1 Project Description

As part of this reconnaissance investigation, USFWS was provided funding with the dual purposes of assessing the feasibility of providing fish passage facilities at the four most downstream dams on the Blackstone River, and determining the construction costs associated with providing the facilities. The rationale for performing actions at all four dams is because the first significant anadromous fish habitat area is upstream of the fourth dam, in Valley Falls Pond. The construction of fish ladders at these dams is considered Phase I of an overall effort to reintroduce anadromous fish to the Blackstone River watershed. Results of the USFWS efforts indicate that it is feasible to provide fish passage at the facilities. A preliminary layout of the location of the fish passage facilities on the dams is provided in Figures 15 to 18. The total costs of providing both upstream and downstream fish passage facilities are $910,000, $245,000, $595,000, and $455,000 for Main Street Dam, Slater Mill Dam, Elizabeth Webbing Mill Dam, and Valley Falls Dam, respectively. A monitoring program is included in the operations and maintenance cost. Land costs at the four dams have not been calculated, however. The cost estimates do not reflect additional costs that may result from requirements by Historic Preservation Offices regarding materials or special construction features.



TYPICAL SECTION
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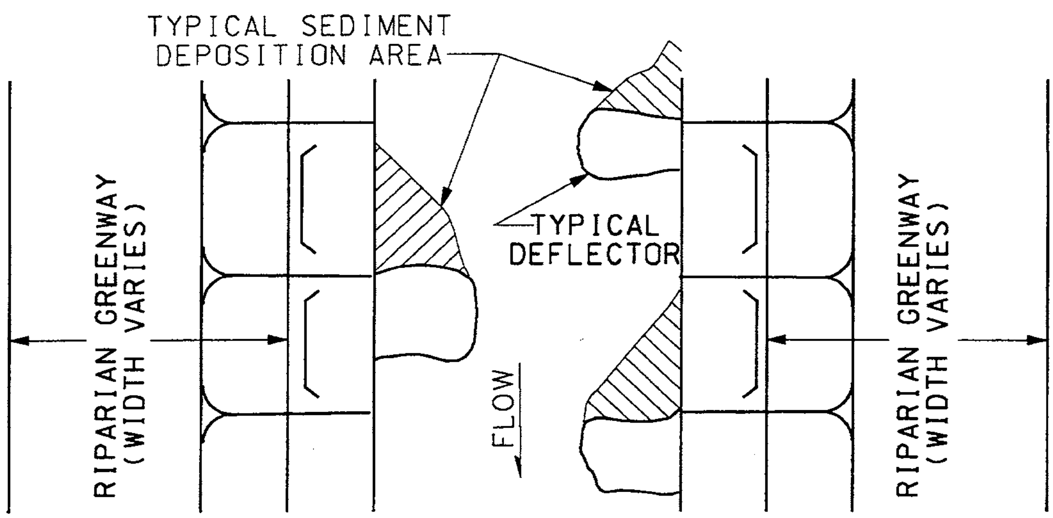
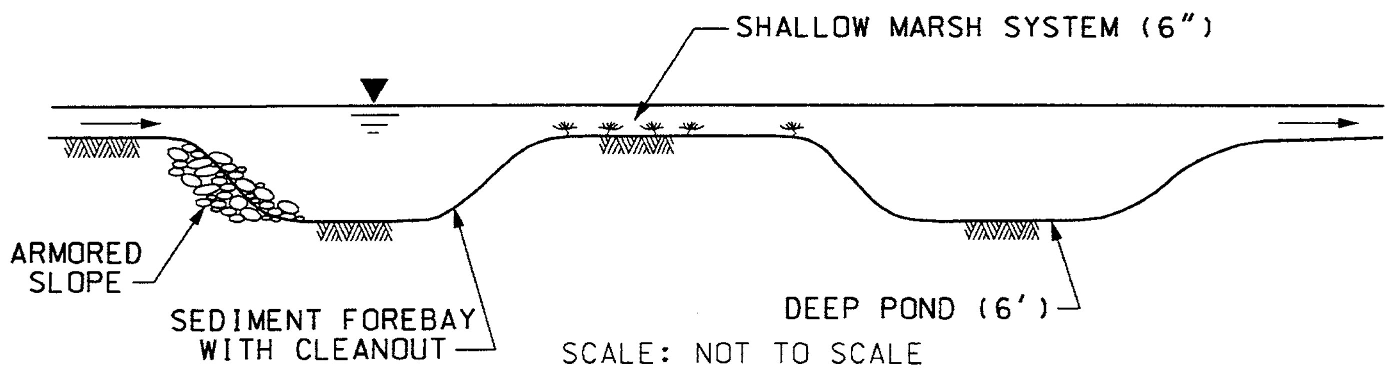


PLAN-TYPICAL REACH
SCALE: 1" = 10'

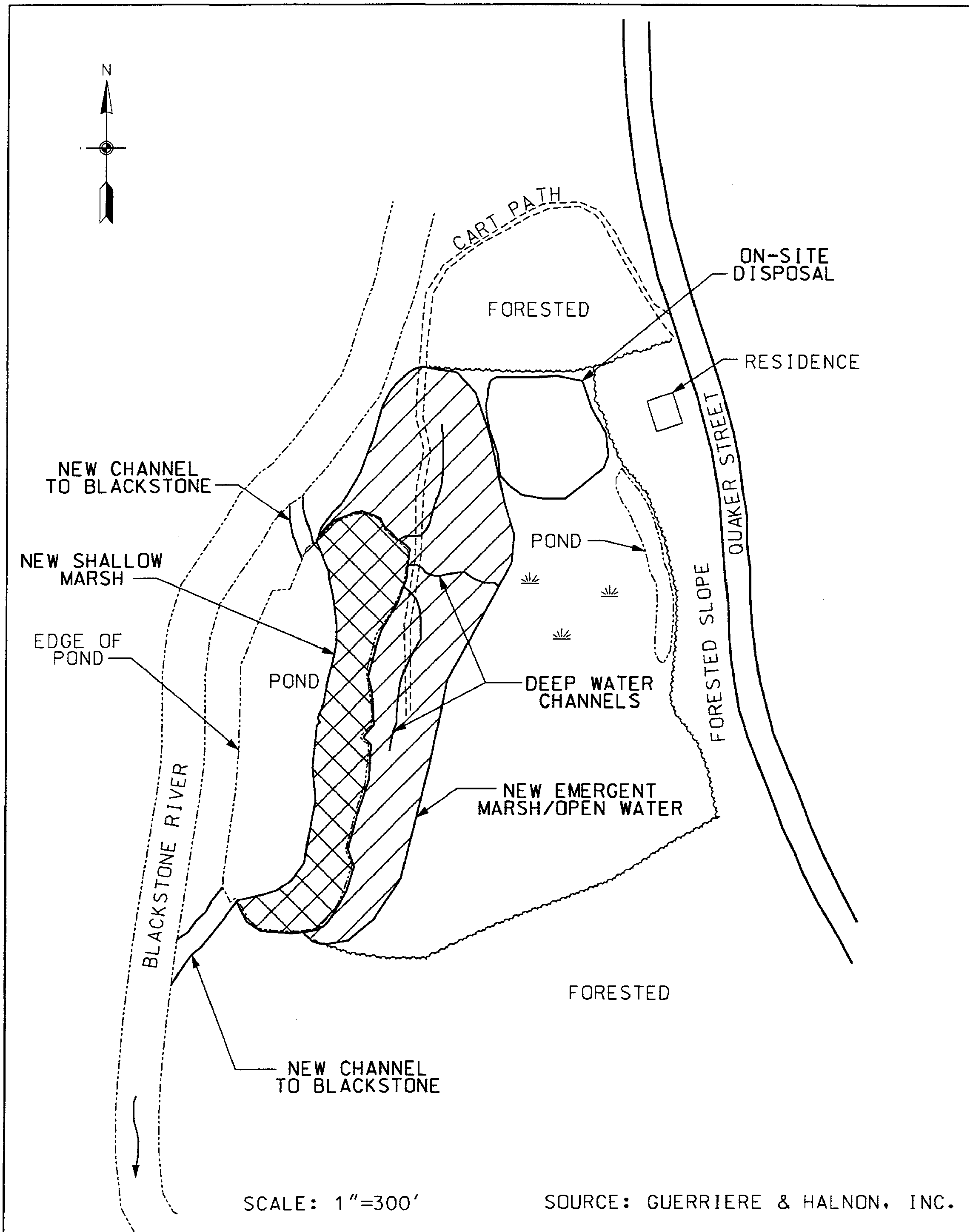


SCALE: NOT TO SCALE

SOURCE: WATERSHED RESTORATION SOURCEBOOK

LONGITUDINAL SECTION FOR BEAVER BROOK SEDIMENT CAPTURE SYSTEM

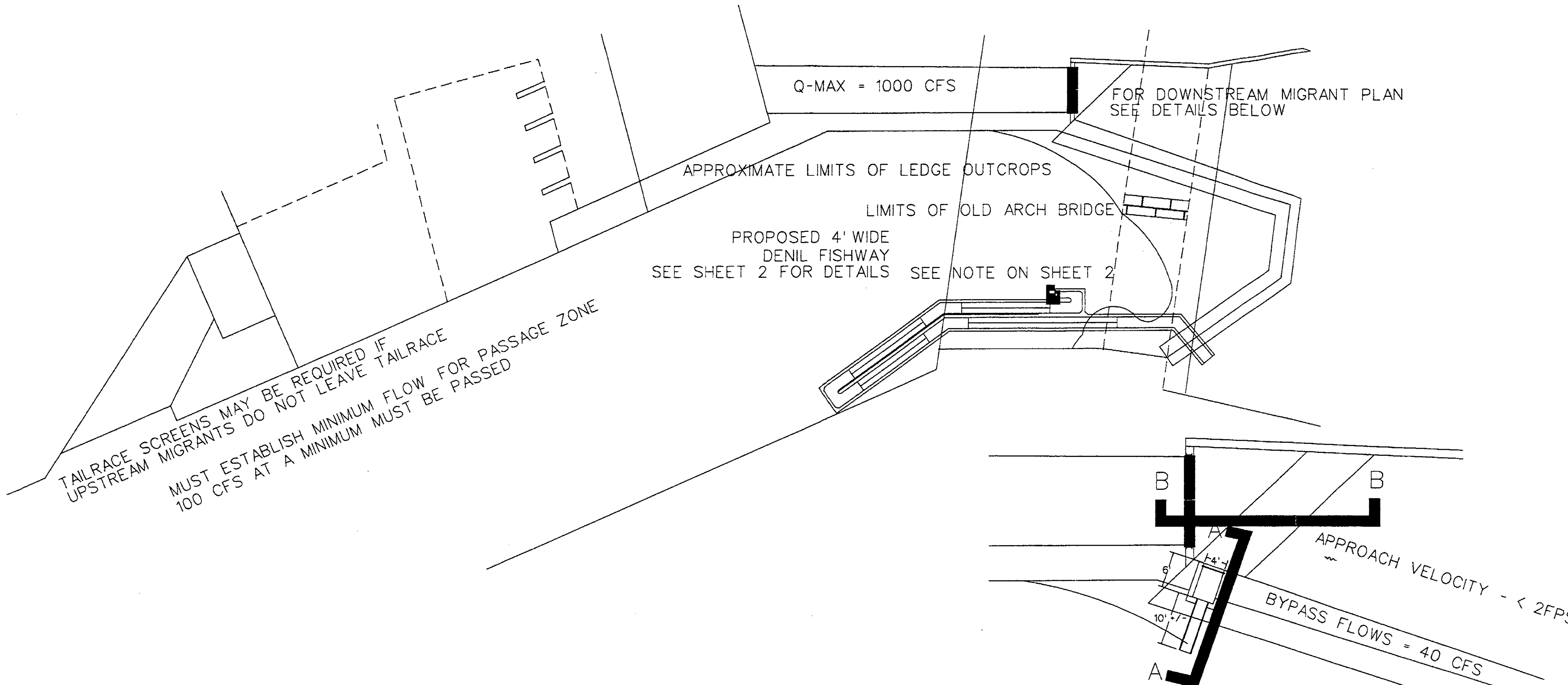
DEPARTMENT OF THE ARMY NEW ENGLAND DISTRICT CORPS OF ENGINEERS WALTHAM, MA	BLACKSTONE RIVER BASIN STUDY BEAVER BROOK PARK WORCESTER, MA FIGURE 13

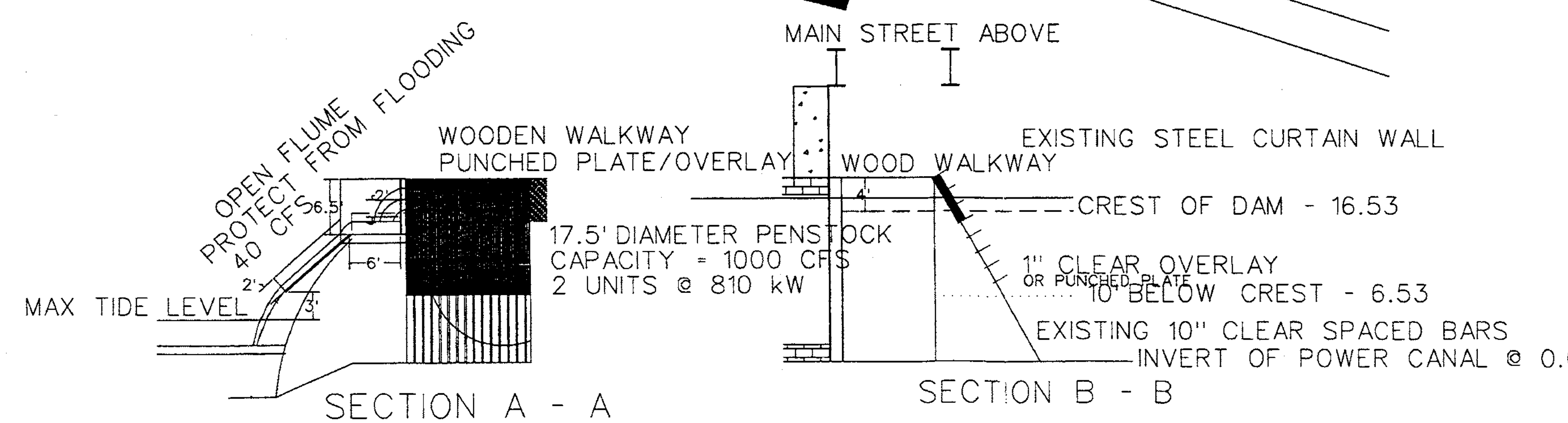


DEPARTMENT OF THE ARMY
NEW ENGLAND DISTRICT
CORPS OF ENGINEERS
WALTHAM, MA

BLACKSTONE RIVER
BASIN STUDY

RIVERDALE GRAVEL PIT
NORTHBRIDGE, MA
FIGURE 14

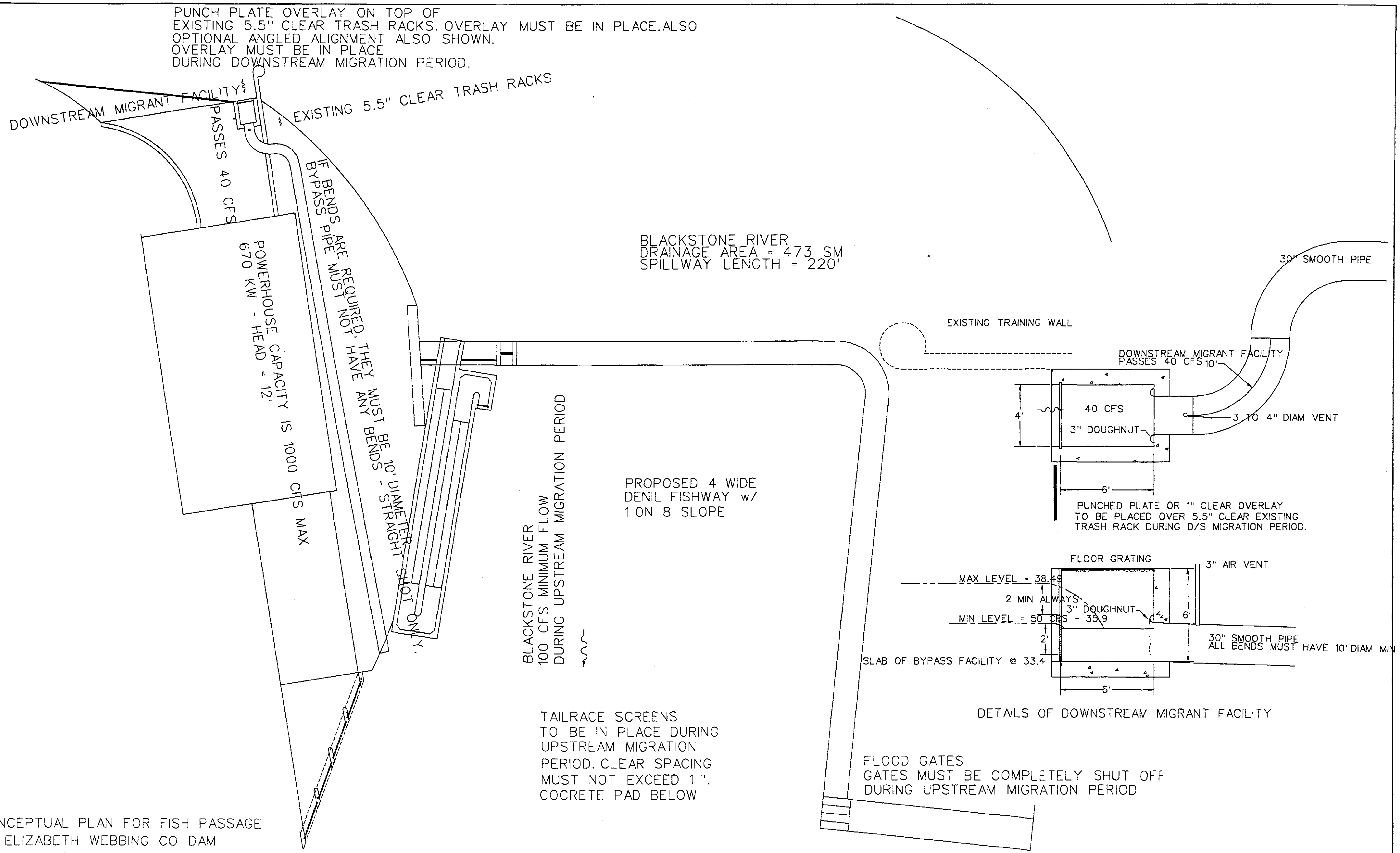




PROPOSED DOWNSTREAM MIGRANT FACILITIES

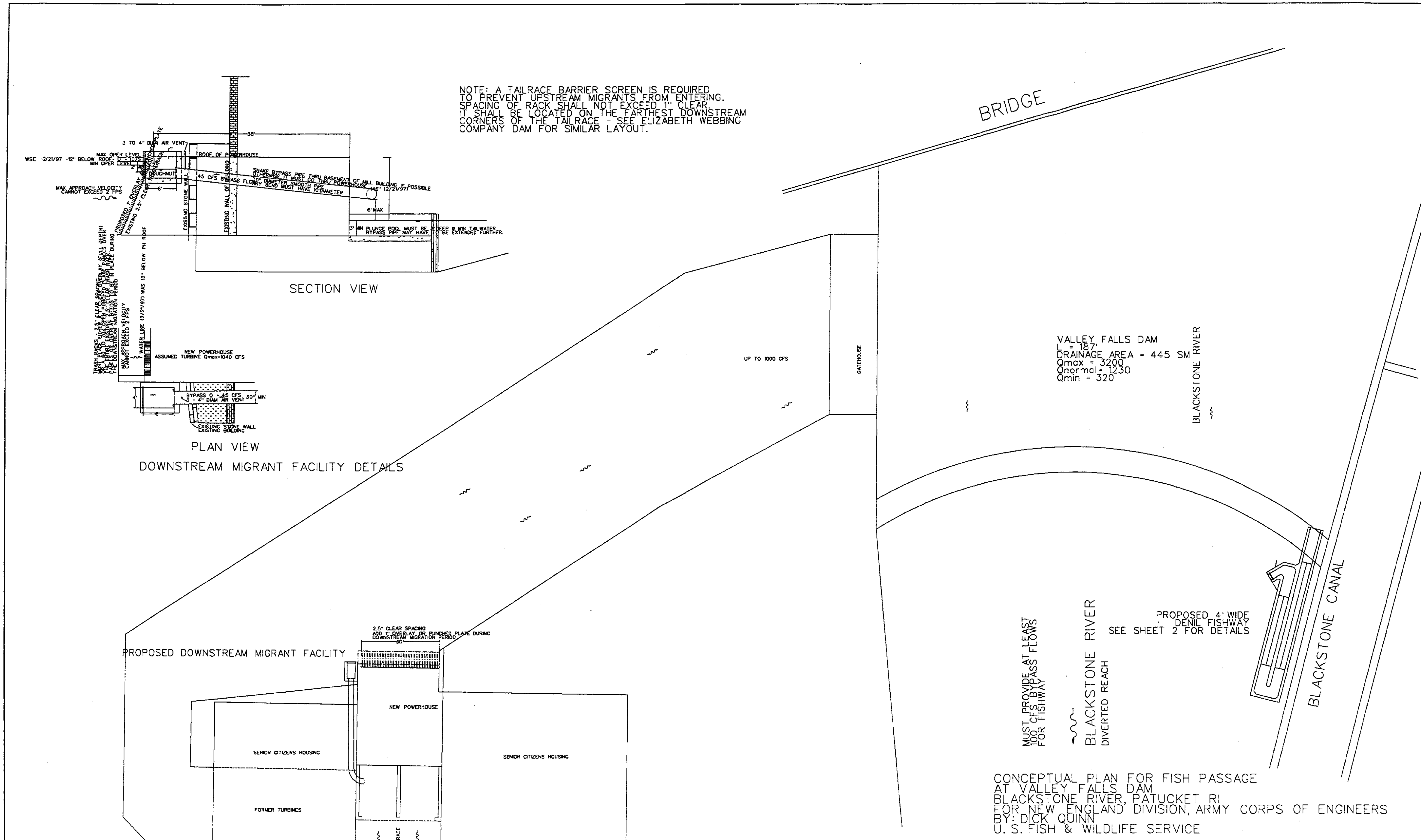
CONCEPTUAL PLAN FOR FISH PASSAGE
AT MAIN STREET DAM
BLACKSTONE RIVER, PATUCKET RI
FOR NEW ENCLAND DIVISION
ARMY CORPS OF ENGINEERS
BY: DICK QUINN
U. S. FISH & WILDLIFE SERVICE
SHEET 1 OF 2
JANUARY 23, 1997

DEPARTMENT OF THE ARMY NEW ENGLAND DISTRICT CORPS OF ENGINEERS WALTHAM, MA	BLACKSTONE RIVER BASIN STUDY FISH PASSAGE MAIN STREET DAM FIGURE 15



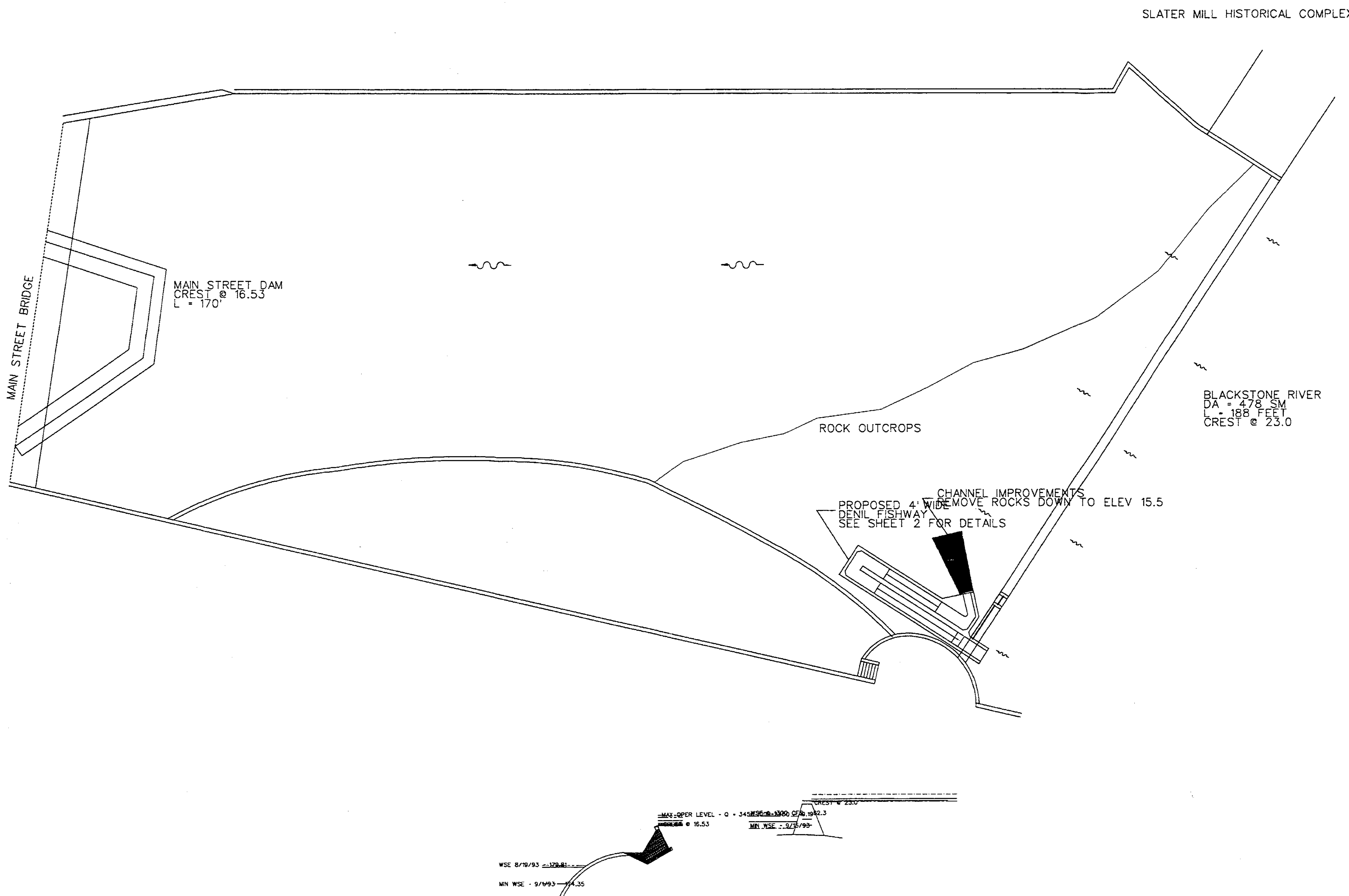
CONCEPTUAL PLAN FOR FISH PASSAGE
AT ELIZABETH WEBBING CO DAM
BLACKSTONE RIVER, PATUCKET RI
FOR NEW ENGLAND DIVISION, ARMY CORPS OF ENGINEERS
BY: DICK QUINN
U. S. FISH & WILDLIFE SERVICE
SHEET 1 OF 2
JANUARY 29, 1997

DEPARTMENT OF THE ARMY NEW ENGLAND DISTRICT CORPS OF ENGINEERS WALTHAM, MA	BLACKSTONE RIVER BASIN STUDY FISH PASSAGE ELIZABETH WEBBING CO DAM FIGURE 16



DEPARTMENT OF THE ARMY
NEW ENGLAND DISTRICT
CORPS OF ENGINEERS
WALTHAM, MA

BLACKSTONE RIVER
BASIN STUDY
FISH PASSAGE
VALLEY FALLS DAM
FIGURE 17



CONCEPTUAL PLAN FOR FISH PASSAGE
AT SLATER MILL DAM
BLACKSTONE RIVER, PATUCKET RI
FOR NEW ENGLAND DIVISION, ARMY CORPS OF ENGINEERS
BY: DICK QUINN
U.S. FISH & WILDLIFE SERVICE
SHEET 1 OF 2
JANUARY 27, 1997

DEPARTMENT OF THE ARMY NEW ENGLAND DISTRICT CORPS OF ENGINEERS WALTHAM, MA	BLACKSTONE RIVER BASIN STUDY FISH PASSAGE SLATER MILL FIGURE 18

Three of the four facilities are hydropower operations regulated by the Federal Energy Regulatory Commission (FERC). The Main St. Dam is "exempted" from formal license requirements, while the Elizabeth Webbing Mill Dam and the Valley Falls Pond Dam have Minor Project licenses. Although the Main St. Dam is exempted, the terms and conditions of its FERC license must be complied with. The FERC licenses of all three of these hydropower dams have provisions that require the operator to construct fish passage facilities when they are the impediments to migration. Construction activities at these facilities can only be triggered with a request from the State of Rhode Island to the USFWS to petition FERC to invoke the requirement. The role of the Federal government in the construction of passage facilities at the lower four dams is uncertain. It is unlikely that Federal funds will be expended for fish passage facilities at FERC-licensed facilities. Consideration of possible Federal actions to facilitate the implementation of facilities to permit the restoration of anadromous fish to the Blackstone River will be given in the feasibility study.

Visual intrusions to the historic facilities such as fish ladders may be discouraged unless the intrusions can be blended into the existing dam without appearing obtrusive, or is situated elsewhere and hidden from view. Alternatives should be selected which effectively accomplish project aims while at the same time, minimize or preferably eliminate, any adverse visual, structural or related impact.

Operational seasons of the facilities are approximately the first week in April to mid-June for adult upstream migration. Adult downstream migration occurs approximately 3 weeks after they pass upstream. The late part of summer is the juveniles downstream migrating season.

Value of the restoration of anadromous fish is somewhat subjective and intrinsic. The restoration is likely to inspire even greater hopes and expectations on the part of the basin's residents. The ecological value of anadromous fish restoration is also difficult to quantify. Restoration will have a positive effect on the overall system ecology, with <u>resident</u> fish populations likely to also benefit due to the food web importance of various life cycles of the fish. Recreational opportunities would also improve. American shad, in particular, are often referred to as the "poor man's Atlantic salmon" due to their fighting and jumping abilities.

6.9 Opportunities at Existing Corps Projects

The Corps of Engineers has authority under the Section 1135 program to undertake modifications to constructed Corps structures or operations to improve fish and wildlife resources. This investigation identified several measures which could be taken to improve aquatic and other habitat at projects in the Blackstone watershed. Any change proposed at a Corps flood control reservoir or Local Protection Project would likely require hydraulic studies and a revision to the Operations and Maintenance requirements, and would require a local sponsor. Projects constructed under the 1135 Program are cost shared 75 percent Federal and 25 percent non-Federal. The types of potential environmental restoration measures are described in the following sections of the report.

6.9.1 West Hill Dam

Although no opportunities to restore wetland or stream habitat were identified at West Hill Dam, a large gravel pit still in operation along the West River near West Hill Dam will, when it ceases operation, offer an excellent opportunity to restore riparian habitat and/or create wetlands. The site is privately owned but is not developable because the Corps owns a flowage easement on the property.

6.9.2 Worcester Diversion Project

There is a potential opportunity to increase flows in the bypass channel of the Worcester Diversion Project during the dry summer months. Presently, flow is diverted only from the Auburn, Massachusetts area (Kettle Brook) to the 2.1 mile-long bypass channel to the Blackstone River (after passing through the 0.8 mile-long diversion tunnel) during floods or in anticipation of them. Although no fisheries resources information is currently available, large numbers of crayfish are harvested commercially near the Route 20 crossing. Mallards commonly nest in the channel. Upstream of Route 20, the channel abuts a large undeveloped area that provides valuable natural habitat.

The bypass channel has a bottom width of about 40-50 feet, a capacity of 6,000 cfs, and un-riprapped bottom and sideslopes. Side slopes are vegetated with grasses, herbs, and small shrubs and trees. The bypass channel is generally wet year round, with flow apparently maintained by several small streams flowing into the channel. Flows in the bypass channel could be increased most likely by a new small pipe placed through the Kettle Brook diversion weir at a low elevation. Flow quantities to be diverted would be investigated during the feasibility study, when impacts to the Kettle Brook and Middle River habitat downstream of the diversion would be examined.

There is a potential opportunity for construction of a sediment capture basin near the downstream end of the 2.1 mile-long bypass channel of the Worcester Diversion Project. The Worcester Department of Public Works, the local sponsor and operator of this project, regularly removes a large amount of sediment from lower reaches of the bypass channel, however, additional sediment undoubtedly reaches the Blackstone River. Construction of an instream sediment control basin would reduce sediment transport to the Blackstone and simplify channel maintenance.

Bioengineering/riparian planting has potential merit along the bypass channel. Planting trees along the edge of the channel and on upper portions of the sideslopes to provide shade could lower stream water temperature during the summer and improve aquatic habitat. Much of the bypass channel passes through open areas with little shade. Trees near the top of the natural channel slopes may have an impact on flood flows which would need to be considered. Currently, trees and shrubs are periodically cut to prevent potential flow obstructions.

6.9.3 Habitat Restoration in Conjunction with Corps Embankments

<u>Alteration of Cross-Sectional Area in Conjunction with Planting Vegetation</u> has potential application at the remaining LPPs. It may be possible to enhance environmental habitat along an existing trapezoidal channel by excavating terraces on either side of the channel and planting them with woody vegetation. Reduction in hydraulic capacity caused by the vegetation and increased eddy currents caused by the terraces may possibly be compensated by the increased cross sectional area of the channel. Construction of a low flow channel may also be possible. Analysis of any hydraulic changes would be necessary during the feasibility phase.

<u>Bioengineering</u> measures to control side slope erosion may also be useful in some areas. Side slopes are eroding in some locations. Planting in the cracks between the stones used for riprapping stream banks may also be appropriate. Current Corps regulations prohibit planting on the river side of flood protection projects. The Corps is, however, examining these opportunities for possible future implementation.

Instream Habitat Improvements have potential application at these LPPs. Eddy rocks and double deflectors could be provided throughout the channel to improve in-stream habitat. Small check dams placed across the channel in a few well-shaded locations may trap sediment and provide deep water pools to improve waterfowl habitat. Small instream structures such as eddy rick, deflectors, and check dams may, however, adversely impact channel floodflow capacity.

VII. SUMMARY OF POTENTIAL OPPORTUNITIES

7.1 Problems, Needs, and Opportunities

The Reconnaissance investigation examined the ecosystem of the Blackstone River watershed and found significant ecological problems including: lost or degraded wetlands, instream, pond and riparian habitat; loss of an historic anadromous fishery; degraded waterfowl habitat; degraded resident fisheries; contaminated sediments; and poor water quality. The study also identified a broad array of potential solutions to address the basin's ecological problems and presents preliminary designs and cost estimates for example projects believed appropriate for the Blackstone River watershed. The projects presented in this report, although not representing the full extent of work required to restore the ecological health of the watershed, would significantly improve the watershed's ecological health, particularly that of the mainstem river. The construction of similar projects throughout the study area would probably be required to achieve a dramatic improvement in the watershed's ecological health. Further studies conducted in the feasibility phase of this investigation will develop a comprehensive plan for restoration of sites to achieve an optimum level of environmental improvement.

7.2 Unresolved Issues

There are several major issues which need to be addressed prior to proceeding with the larger restoration projects. The first question concerns the risk posed by contaminated sediments. A thorough assessment of the ecological and human health problems caused by contaminated sediments is a critical first step in developing a restoration plan for the watershed. The preliminary risk assessment performed by the Corps on surficial sediments in Fisherville Pond in Grafton, Massachusetts indicated that the hazard probably does not warrant extensive and extremely costly remediation actions. This conclusion was based, however, primarily upon an extremely limited number of samples taken by the Corps from the top layer of sediment at the bottom only of the Fisherville impoundment. It is unknown what the ecological and human health risks of sediments from various depths (below the pond bottom) are, or how the risk from sediments changes under various conditions including aerobic and non-aerobic conditions. Since limited sediment coring performed by others indicates that contamination worsens with depth, risks may also increase with depth. This may be very significant, since it could adversely impact on the feasibility and/or cost of dredging opportunities and may impact if there is a Federal interest to restore lost or degraded habitat. Comprehensive sediment sampling and analysis, and risk analysis should be performed to thoroughly assess the restoration opportunities in the basin. In addition to concerns regarding human and ecological risks, there could be concerns by others that may limit sediment options. If sediments must be remediated, the likelihood of projects being implemented on a major scale may be reduced.

Further studies are also required to gain a better understanding of the problem of resuspending sediments. Sediment sink and resuspension areas, and sediment loads should be identified under a broad range of flow conditions to identify restoration opportunities appropriate for each area. At present, many of the impoundments are silted in and new sediments may be passing through the impoundments without settling. Therefore, it is unclear if the more contaminated existing sediments are being capped with sediments from new sources that are likely cleaner. If sediments settle out during normal flows, but become resuspended and wash downstream (eventually to Narragansett Bay) during high flow events, the long term solutions selected for individual areas may accordingly be affected.

This Reconnaissance study also identified the need to gain a better understanding of the role of degraded water quality and the cause of water toxicity. An understanding of the connection between water quality and the health of the environment can be applied in the further actions to control point and non-point sources of water quality contamination.

Another issue that must be resolved prior to formulation of projects involves spillway and freeboard criteria for non-Federal dams which generally do not meet Corps or current state standards. The Reconnaissance study assumed that restoration projects which involve the rehabilitation or reconstruction of non-Federal dams would retain the current spillway and freeboard criteria. This was based on discussions with the Massachusetts DEM's Office of Dam Safety concerning the Fisherville Pond prototype project and Fisherville Dam's rehabilitation. The historic designations of many of the dams may also impact modification to the dams. This issue will be addressed in greater detail during the Feasibility phase.

Still to be resolved is the role of the Corps with respect to hazardous, toxic, and radioactive waste (HTRW). Corps involvement in HTRW as it relates to environmental restoration projects is outlined in ER 1165-2-132, *"Hazardous, Toxic, and Radioactive Waste (HTRW) Guidance For Civil Works projects"*. Corps Civil Works policy is to avoid project activities in HTRW contaminated areas. When unavoidable, the local sponsor shall be responsible for the accomplishment of all HTRW response actions at 100 percent non-project cost. ER 1165-

2-132 states that HTRW includes any materials listed as a hazardous substance under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). A review of the limited sediment data indicates the presence of some contaminants identified in the CERCLA list of hazardous substances. It is not known, however, if the presence of these contaminants will require any specific response actions on the part of the sponsors or the Corps. This will be addressed as part of the Feasibility study.

7.3 Watershed Plan Summary

Section V of this report discusses the types of restoration projects which could be constructed to address the ecological problems found to impact the Blackstone River watershed. The report also develops plans and cost estimates for example restoration projects to illustrate the application of these techniques. As stated above, the report assumes that similar projects would be constructed throughout the watershed to achieve the desired level of restoration. The following is a discussion of the steps necessary to identify, assess and prioritize restoration projects within the watershed. These actions are necessary prerequisites and should be considered the first step in the development of a restoration plan for the watershed.

A comprehensive inventory of the basin's wetland sites should be performed, most likely through the interpretation of 1:40,000 color infrared aerial photography coupled with review of soils maps and ground truthing for identification and ranking purposes. The survey is needed to identify filled wetlands, wetlands with constricted drainage, and those that have been drained by ditches. The comprehensive inventory will serve to identify small scale wetland restoration opportunities. Priority should be given to restoration projects which would restore habitat for rare, threatened, or endangered species or relatively common species thought to be in decline, restore rare wetland community types, improve water quality in the basin, and benefit fish and wildlife populations.

Given expected development in the Blackstone basin over the next several decades, priority should be given to protecting large blocks of remaining riparian habitat and adjacent uplands not protected by state wetlands or river protection regulations. Potential greenways and riparian or upland corridors which link isolated patches of riparian habitat should also be targeted for protection. The corridors allow wildlife to migrate between patches, helping to preserve species diversity and maintain genetic variability among populations. A study is needed to map remaining riparian habitat in the basin and prioritize areas in need of protection based on their habitat value and vulnerability to future development.

Opportunities to restore large blocks of riparian habitat and riparian corridors in the basin should also be pursued. This survey identified a few restoration opportunities. Many other riparian restoration opportunities undoubtedly exist in the watershed and a thorough basin wide study is needed to identify them.

An anadromous fisheries restoration plan should be developed. The purpose of this plan would be to identify potential anadromous fish habitat areas, predict fish populations, identify issues and concerns relative to habitat quality and of implementation of fish passage, and establish a logical phased effort and timetable for implementation.

A comprehensive inventory of the biological resources of the basin, and of individual areas, is needed to identify ecological needs of the basin. This Reconnaissance Study identified these deficits based upon the very site specific, limited, and/or out of date information available.

Instream flow requirements sufficient to protect biological resources and possibly for recreational purposes should be established for those reaches below major water diversions, including hydropower operations. This would identify the need for possible increases in flow bypasses at these facilities. For hydropower facilities, involvement by FERC would be necessary. FERC's involvement would also be required in ending the flow fluctuations identified as a problem in this report.

An inventory of dams throughout the basin, and an assessment of the purpose, value, condition and threat posed by each of the dams should be undertaken. If the liability of a dam outweighs its benefits (including historic benefits), the dam should probably be removed to restore riverine habitat and allow fish and boat passage. Information gained in the sediment sampling program will be particularly valuable in the decision-making process on dam removal or retainment, since it is likely that measures to address the washout of sediments associated with dam breaching will be costly.

Restoration areas must then be prioritized in light of the identified ecological deficits. Recreational needs ought to be considered in this planning process. The types of projects formulated to address these deficits as part of a comprehensive watershed plan are expected to resemble those generic and prototype solutions described in this report. A comprehensive watershed plan would be formulated in the feasibility phase.

7.4 Opportunities for Corps of Engineers Involvement

The Corps of Engineers has identified the restoration of ecosystems and their associated ecological resources as a priority project purpose. Within the Civil Works program, priority is given to projects which restore degraded ecosystem functions and values, including hydrology, plant and animal communities, to a less degraded ecological condition. EC 1105-2-210 "Ecosystem Restoration in the Civil Works Program" establishes that the Corps principal focus in ecosystem restoration is on those ecological resources and processes that are directly associated with, or dependent upon, the hydrologic regime of the ecosystem and watershed. The EC states that *"Those restoration opportunities that involve modification of hydrology or substrate are most likely appropriate for Corps initiatives"*. Simply stated, the Corps mission in ecological restoration is linked to improving fish and wildlife resources and values.

This Reconnaissance investigation describes numerous actions that can be taken to address degraded habitat and other ecological problems within the watershed. Many of these actions clearly are within the realm of the Corps of Engineers environmental restoration mission. Major areas that could best be addressed by the Corps, and also have potential widespread applicability, are discussed in the following paragraphs.

The Reconnaissance study has determined that the loss and degradation of wetland habitat is a serious problem within the Blackstone River watershed. The construction of wetlands restoration projects, such as the “Lonsdale Drive-In” project, to address wetland habitat deficiencies within the study area is a potential role for the Corps consistent with its environmental restoration mission. Additional studies are required to identify and prioritize additional locations for wetlands restoration projects. One potential opportunity is the conversion of abandoned gravel pits into shallow emergent/open water habitat areas. The best opportunities for restoration are likely those along the rivers. The construction of wetland habitat areas at the gravel pit sites will not directly replace wetland habitat at that location, but could be a cost effective means of restoring habitat lost at other locations elsewhere in the watershed.

The Corps of Engineers also has a role in the restoration of both wetlands and open water habitat behind the numerous dams in the watershed. Restoration projects such as the one proposed for Fisherville Dam benefit the ecological health of the watershed by providing additional waterfowl and open water/emergent wetland habitat. Restoration activities at these projects potentially include dredging, re-vegetation, construction of hydraulic control structures and, in some cases, the rehabilitation of existing dams. The restoration of habitat at these impoundment locations is consistent with the Corps mission of environmental restoration. Moreover, because of its experience with dredging and dam construction, the Corps may be the only public organization capable of constructing these types of restoration projects.

Another potential role for the Corps is to address the potential loss and degradation of wetland and other habitat areas in the watershed due to the failure of one or more of the deteriorating dams on the mainstem Blacktone River. The failure of one of these dams would result in the loss of the habitat behind the dam(s) and the release of highly contaminated sediments causing habitat loss both downstream of the dam(s) and in Narragansett Bay. The majority of the dams on the mainstem were constructed to support industries along the river. Most of these mills are no longer operational and the ownership of the dams have been transferred to real estate holding companies or are in Federal receivership. While everyone agrees that dam maintenance is the responsibility of the dam owner, in reality, most of the owners lack the financial resources to make the necessary repairs to the dams. The issue of dam maintenance is essentially at a stand-still while the dams continue to deteriorate, eventually leading to more serious environmental and possibly human health problems.

Although the repair of non-Federal dams is a recognized non-Federal interest, the situation on the Blackstone River seems to warrant special consideration. A considerable Federal investment has already been made to improve the water quality and improve the ecological health of the watershed. Similar investments have also been made to improve the health of Narragansett Bay. One reason for Congressional designation of the region as a National Heritage Corridor was to foster preservation of the Blackstone River watershed's infrastructure, including its dams. Also, it would seem short sighted for the Federal government to continue to ignore ecological disasters associated with impending dam failures. The cost to clean-up the contamination and to restore the impacted habitat areas will far outweigh the costs to stabilize the dams. Studies should be undertaken during the feasibility phase to assess the condition of the mainstem, non-hydropower dams, particularly those with earth embankments, and to estimate the costs of repair. The Corps of Engineers should consider undertaking the repair of any unstable dams as a component to a restoration plan for the watershed.

The feasibility phase of this study should include an evaluation of under-utilized dams throughout the watershed to assess their possible removal to restore river/stream habitat. If feasible, the demolition of existing dams to restore habitat could be a role for the Corps.

The restoration of anadromous fish is also a recognized area for Corps participation. This study determined that it was feasible to construct fish passage facilities at the lower four dams on the river and advocates the development of a phased plan for the restoration of anadromous fish to remaining portions of the watershed. However, the role of the Federal government in the construction of passage facilities at the lower four dams is uncertain because of the provisions in the FERC licenses that require the operator to construct fish passage facilities when they are the impediments to migration. Future studies will address this issue and consider possible Federal actions to facilitate the implementation of facilities to permit the restoration of anadromous fish to the Blackstone River.

VIII. IMPLEMENTATION OF WATERSHED PLAN

This section describes the proposed implementation of the restoration plan for the Blackstone River watershed. The proposed plan consists of a comprehensive analysis of the problems and opportunities of the entire watershed, including an assessment of the opportunities offered by each sub-basin with respect to the needs identified for the entire watershed. This plan will undoubtedly require considerable coordination and negotiation, and will likely be limited by the amount of funds available at all levels of government. Because of the uncertainties associated with the plan, the report describes implementation in general terms only.

8.1 Potential Federal, State, and Local Implementation

The implementation of a comprehensive watershed restoration plan will involve strong participation at all levels of government. This section of the report discusses the likely roles of various Federal agencies and state and local governments in the completion of the restoration plan. This section also discusses which agency would have the primary responsibility for various elements within the plan. This determination is made based upon agencies' missions and current programs. Also identified are the cooperating agencies that have secondary responsibilities that will likely involve coordination and input into plan development and management, and technical assistance. Strong public involvement and interagency coordination will be critical to the successful implementation of the Blackstone River watershed restoration plan.

8.1.1 Federal Responsibilities

The Corps of Engineers is proposed to be the lead Federal agency in implementing the watershed restoration plan. There is also a strong need for other key Federal agencies to play a large role in plan implementation. These agencies include the U.S. Environmental Agency, Natural Resources Conservation Service, U.S. Fish and Wildlife Service, National Parks Service, U.S. Geological Survey, National Marine Fisheries Service, Federal Energy Regulatory Commission, and possibly the Federal Emergency Management Agency.

The Corps of Engineers has authority to participate in projects to solve water resources problems associated with degraded fish and wildlife habitat. Recreational and other objectives may also be included, but only as secondary project features. The Reconnaissance study has identified a number of water resources problems which fall under the purview of the Corps of

Engineers and could be addressed using current Corps authorities. The recommendation of this report is for the Corps to continue this investigation to identify potential Corps projects for the restoration of fish and wildlife habitat. The Corps should conduct a feasibility study to investigate the creation and restoration of terrestrial, riparian, and aquatic habitat. Further economic, environmental, and engineering investigations must be performed to determine the most feasible solutions to the problems. As required in the Water Resources Development Act of 1986, 50 percent of the feasibility study is funded by the Federal government and the remaining 50 percent must be funded by non-Federal sponsors. Current law requires that the cost of construction for most ecosystem projects be cost shared 65 percent Federal and 35-percent non-Federal. The majority of the environmental restoration efforts identified thus far in the study process appear to fall under this requirement. Restoration projects at existing Corps of Engineers constructed facilities can also be implemented under the Corps Section 1135 program which only requires a 25 percent non-Federal cost share. Actions related to improving water quality, unless directly related to improving fish and wildlife habitat, are not eligible for Corps implementation. Water quality is a significant problem in the watershed, but is within the purview of EPA and state regulatory agencies.

8.1.2 State and Local Responsibilities

The role of the states and local entities in the watershed plan will be established upon determination of the scope of actions in the watershed. States and local entities already have taken numerous steps complementary to some of the general goals of comprehensive watershed planning. An example of such actions are the recently enacted state and local regulations in Rhode Island and Massachusetts requiring regulatory review for projects occurring in or near wetlands and riverine buffer zones. This action is likely to reduce the rate of wetland loss in the basin.

State and local agencies are charged with the responsibility of improving water quality. The Corps of Engineers does not presently have the authority to participate in projects solely for water quality improvements. Whether Corps projects are implemented in the watershed or not, State and local agencies can perform a broad array of measures to improve water quality including point- and non-point source control, community education, and an assortment of Best Management Practices (BMPs). Although source control through permitting and BMPs should reduce some of the loading to the river (especially fecal coliforms, suspended solids, BOD_5, and nutrients), these actions alone will not eliminate all pollutants from entering the river.

State and local governments and conservation organizations should increase funding for acquisition of conservation lands and encourage landowners to place conservation easements on private land. Use of natural resources damage settlements to acquire conservation lands and creative real estate arrangements, such as land swaps to protect valuable natural areas, should be encouraged. In moderately to highly developed areas, the focus should be on restoring or preserving large tracts which are linked or in close proximity to other significant natural areas. Restoration of the Lonsdale Drive-In site and the Lonsdale Island Gravel Pit in Rhode Island, for example, would complement the nearby Lonsdale Marshes. These projects would also provide valuable rearing habitat for juvenile alewife and blueback herring once fish passage at the lower four dams on the Blackstone River is provided.

Opportunities exist to strengthen existing wetland protection laws and regulations and improve compliance though public education. States and local communities should consider strengthening regulations against development in the wetland buffer zone and near vernal pools. Most authorities suggest that at least a 100 foot buffer is required to protect wetland water quality and offer minimal protection to wildlife habitat value. Even with stringent regulations in place, many wetlands, particularly those in residential areas, are vulnerable to gradual long-term loss due to disposal of small quantities of yard waste and other materials. Application of pesticides near wetlands is also a concern, especially near vernal pools supporting sensitive amphibian populations. Enhanced public education is needed to address these problems and inform the public of other best management practices to protect wetlands and vernal pools.

8.2 Overview of Feasibility Phase

8.2.1 Purposes of the Feasibility Phase

Major water resources studies undertaken by the Corps of Engineers are conducted in two phases; a reconnaissance phase and a feasibility phase. The two-phase study procedure is designed to encourage non-Federal participation throughout the study process and to increase the certainty that planned projects will be implemented.

The purposes of the feasibility phase are as follows:

- To conduct detailed engineering, economic, environmental, and cultural investigations to support plan formulation and evaluation;

- To identify the National Economic Development (NED) plan (if appropriate);
- To identify the National Ecosystem Revision (NER) plan;
- To identify environmental restoration projects that are consistent with Corps implementation policy, produce high priority environmental outputs, and are incrementally justified;
- To comply with National Environmental Policy Act (NEPA) requirements by preparing appropriate environmental documentation;
- To estimate costs and benefits to a level of detail suitable for project justification, if applicable;
- To determine the appropriate construction cost-sharing arrangements and obtain non-Federal support, as necessary;
- To prepare appropriate documentation for Federal project authorization; and
- To recommend favorable projects for authorization and construction, if appropriate.

8.2.2 Anticipated Product

The anticipated product of the feasibility phase will be a report which addresses environmental restoration measures for the Blackstone River watershed. This report will be accompanied by the appropriate documentation (Environmental Impact Statement or Environmental Assessment) to comply with NEPA. The report will provide all the necessary documentation to permit project authorization by the U.S. Congress for construction of a Federal project(s), if justified. The report will build upon the information contained in this reconnaissance report and will include the following:

- A detailed examination of environmental restoration opportunities in the Blackstone River watershed;

- A re-evaluation and prioritization of the various sub-watersheds within the study area to determine where environmental restoration projects should be implemented;

- Data collection and sampling to ascertain existing stream characteristics, including sediment quality and toxicity;

- The conduct of a sediment loading study;

- A comprehensive assessment of ecological and human health risks posed by the contaminated sediments;

- The formulation of practical restoration project alternatives considering the nature of the problem, site characteristics, and area resources;

- The assessment of the environmental effects of the possible solutions and preparation of environmental documentation;

- The investigation of possible impacts to cultural resources with results and determination of effects coordinated in accordance with Section l06 (Public Law 89-665, as amended) responsibilities;

- Coordination with the USFWS, including receipt of a Fish and Wildlife Coordination Act Report;

- The preparation of typical design drawings and quantity estimates;

- The development of estimated project costs and benefits;

- The evaluation and ranking of feasible solutions;

- The preparation of a preliminary hazardous, toxic, and radioactive waste assessment in accordance with the Clean Water Act;

- Compliance with other environmental laws and regulations, as appropriate;

- The implementation of a public involvement program to ensure that the public's concerns are addressed and that the public is kept apprised of what the Corps is proposing;

- Analysis of project implementation arrangements, including construction cost-sharing requirements and an ability-to-pay analysis of the non-Federal sponsor's project financing plan;

- The preparation of a Project Management Plan (PMP) which describes the tasks required during the Preconstruction Engineering and Design (PED) phase and associated costs; and

- The development of recommendations for authorization and construction, if a project(s) is economically justified and supported by non-Federal sponsors.

8.2.3 Feasibility Cost-Sharing Agreement

Section 905(b) of the Water Resources Development Act of 1986 requires that Federal funds be expended for all costs associated with the reconnaissance phase. However, Section 105(a)(1) requires that the cost of a subsequent feasibility phase be shared equally (50/50) between the Federal government and a non-Federal sponsor(s).

Up to one-half of the non-Federal contribution, or one-quarter of the total cost of the feasibility phase, may be in the form of in-kind services. In-kind services are those tasks performed and paid for by the non-Federal sponsor which are in direct support of the feasibility study effort. An example of an in-kind service by the sponsor would be coordination of the public involvement effort mentioned earlier. While all in-kind services should be in support of the particular study, it is permissible for non-Federal sponsors to re-orient existing programs and ongoing work to complement the Corps feasibility study.

In order to proceed beyond the reconnaissance phase, the Federal government and a non-Federal sponsor(s) must agree that the proposed project is in the Federal and non-Federal interest and must then negotiate a feasibility cost-sharing agreement (FCSA) that commits both parties to equally sharing the cost of the feasibility phase. The FCSA is intended to promote a partnership for the conduct of the feasibility phase. This agreement sets forth the management structure, obligations of the signatories, methods of payment, resolution of disputes, methods for termination or suspension of the feasibility study, and other general contractual matters. A model FCSA is contained in Appendix D.

Federal funds to initiate the feasibility phase may be allocated only after a negotiated FCSA has been prepared, and all documents have been certified by the Corps higher authority. The feasibility phase can then begin after execution of the FCSA and receipt of both Federal and non-Federal funds.

8.2.4 Project Study Plan

As part of the feasibility cost-sharing agreement, a preliminary Project Study Plan (PSP) is prepared and negotiated. The PSP documents the specific Federal and non-Federal efforts which will be required to conduct a particular feasibility phase. The PSP is appended to the FCSA, and lays out the work tasks, costs, and schedules for the entire feasibility phase. It also furnishes a basis for identifying the in-kind services to be provided by the non-Federal sponsor and for negotiating the value of these services. Significant changes to the PSP during the feasibility study will require a modification of the FCSA. The draft PSP for the Blackstone River watershed is contained in Appendix D.

8.2.4.1 **Feasibility Study Work Tasks.** Major work tasks for a feasibility phase are identified in terms of the general activities which are included in the Corps of Engineers' standard study cost estimate for general investigations. These tasks, in turn, are further divided into sub tasks which are specifically applicable to the Blackstone River Watershed Study. The sub tasks cover further refinements of the information already gathered, development of new information where data was not previously available, detailed assessments and evaluations of proposed plans, management and coordination activities, and report preparation and processing. A tentative list of sub tasks is provided in the preliminary draft PSP contained in Appendix D.

8.2.4.2 **Feasibility Study Cost Estimate.** Once the work effort is identified, a cost estimate is developed for each of the individual sub tasks. A preliminary total estimate for the feasibility phase of the Blackstone River Watershed Study is $2.7 million. The cost of the feasibility study has not been broken down by state. The final study cost will be dependent upon the exact scope of activities agreed upon by the Federal government and the non-Federal sponsor(s).

A refinement of sub tasks and estimates of cost will be prepared once the scope and direction that the non-Federal sponsors would like to take is established.

8.2.4.3 **Feasibility Study Completion Schedule.** The schedule for a typical feasibility phase covers 24 to 36 months, including a public review period. Development of a firm schedule for the Blackstone River Watershed Study would be part of the negotiations leading to a final FCSA. The feasibility study initiation date is tentatively scheduled for January 1998. The feasibility phase can begin only after approval and certification of the reconnaissance report, negotiation and execution of the FCSA, and receipt of both Federal and non-Federal funds.

8.2.4.4 **Corps of Engineers Project Management Structure.** Negotiations, general study guidance, study conduct, and policy questions will be handled through a formal management structure composed of representatives from both the Federal government and the non-Federal sponsor. A study management team composed of Federal and non-Federal participants will perform routine activities involving problem identification, plan formulation, and project evaluation. An executive committee will also be organized to provide overall study guidance, to participate in issue resolution conferences, and to resolve any disputes that may arise. Membership on the executive committee is expected to include the District Engineer, his chief planner, and personnel of commensurate levels representing the non-Federal sponsor(s).

The management structure of the Corps is such that during the feasibility phase, there will be both a study manager and a project manager. Their primary responsibilities will include tracking the budget and schedule and interfacing with the local sponsors on major issues. The study manager will be from the Engineering/Planning Division, will be responsible for all of the technical work performed during the feasibility phase, and will act as a contact on technical issues for local sponsors. The project manager will be from the Programs and Project Management Division, but may have less involvement in the everyday workings of the study. This person will maintain continuity throughout the feasibility, PED, and construction phases of the project.

8.2.5 Identification of Potential Non-Federal Sponsors

The potential non-Federal sponsors are the Massachusetts Executive Office of Environmental Affairs and the Rhode Island Department of Environmental Management. These potential sponsors were represented on the Technical Advisory Committee, and were involved with the Corps Planning Assistance to States "Blackstone River Restoration Study" completed in

November 1994, and in this reconnaissance study. Letters of support from the potential sponsors stating their concurrence with the reconnaissance report recommendations and their willingness to negotiate a FCSA are included in Appendices C and D.

IX. CONCLUSIONS

The Blackstone River region has long been recognized as the birthplace of the American Industrial Revolution. In the 1790s, Samuel Slater established the first water-powered textile mill on the Blackstone River in the city of Pawtucket, Rhode Island. Over the next century, numerous industries located in the region to take advantage of the water power offered by the river. In the 1820's, a canal system was constructed along the Blackstone River to link the port city of Providence, Rhode Island with the city of Worcester, Massachusetts. During the height of the Blackstone River Valley's prosperity, between the Civil War and World War I, the river was known as "the hardest working river in America". In recognition of the Blackstone River's significance in the Nation's history, Congress designated the region as a National Heritage Corridor.

Unfortunately, significant ecological damage accompanied industrial development in the Blackstone River watershed. The river and its tributaries were extensively dammed for water storage and hydropower purposes, changing the aquatic environment from that of a free-flowing river to a string of warm water impoundments connected by short stretches of free-flowing river. The widespread practice of unregulated discharges of municipal and industrial wastes into the basin's waterways also accompanied this development. Although this has ceased, millions of cubic yards of contaminated sediments remain in the impoundments of the Blackstone River. The sediments tend to become resuspended during high flows, impacting water quality, and eventually washing into, and degrading, Narragansett Bay habitat.

The report describes the resources of the Blackstone River basin and its ecological problems, determined to be the loss and degradation of the basin's wetlands, riparian, riverine and pond habitat, a lack of once-prevalent anadromous fish, and degraded water and sediment quality. Habitat historically has been destroyed by filling, encroachment, channelization, and the damming of the river. Development pressures on the basin continue, however, and further habitat loss and degradation are expected to result. The dams, which play a crucial role in many of the ecological aspects of the watershed are, in general, poorly maintained and siltation is allowed to occur unabated. The resources protected, and sometimes created, by these dams are consequently threatened by failure of the dams, or the draining of the impoundments by owners to reduce the threat of failure. The poor condition of many of the basin's dams poses a threat to the ecological environment and to public safety. The failure of the dams could result in not only a loss of habitat in the formerly impounded areas, but also in wetlands, riverine, and pond habitat downstream of the dam when the accompanying washout of impounded sediments occurs.

The ecological and human health risks from exposure to the contaminated sediments remains largely unassessed as does the impact of sediment resuspension on water quality in various river segments. Improvements in water quality due to point and non-point source control may be offset by the continued destruction or disturbance of the fish and wildlife habitat.

The Reconnaissance investigation identifies a broad array of potential solutions to address the basin's ecological problems and presents preliminary designs and cost estimates for example projects believed most applicable in the Blackstone River watershed. One of the best opportunities to achieve significant ecological improvement in the watershed is to improve habitat areas at the existing impoundments. The Corps, through coordination with Federal, State and local agencies, and citizen groups, selected the Fisherville Pond site in Grafton, Massachusetts, as a prototype restoration project. Two alternatives are presented for Fisherville Pond, primarily to restore and enhance waterfowl habitat. Alternative 1 involves stabilization of the dam, reconstruction of the outlet works, re-vegetation of degraded habitat areas, dredging of potholes in the wet meadow areas, and establishment of a 200-foot vegetated riparian buffer on the eastern side of the pond. Alternative 1 would restore 9.1 acres of valuable lost waterfowl habitat and improve the quality of the remaining habitat in the impoundment area. The estimated cost of Alternative 1 is $1,100,000. Alternative 2 would expand on Alternative 1 by dredging 25 acres of wet meadow habitat to provide additional open water and emergent habitat. A range of costs are provided for Alternative 2 to reflect the uncertainty associated with the quality of the sediments in the impoundment. The cost of Alternative 2 without any capping requirements is $2,120,000. If future studies identify the need to cap the excavated material, the cost of the project increases to between $3,560,000 and $6,900,000, depending on the type of capping required.

The Reconnaissance investigation identifies the continued deposition of sediment as a significant problem affecting the watershed. One of the project features presented to address this problem is the construction of a sediment capture pond at an existing impoundment. The prototype project presented in the report is Singing Dam in Sutton, Massachusetts, located several miles upstream of Fisherville Pond. The project would consist of initially dredging approximately 120,000 cubic yards of material. Depending on the effectiveness of upstream sediment control measures, the impoundment would require maintenance dredging perhaps every 5 to 10 years. The estimated cost of the project is $3,020,000. Dredging of the impoundment would greatly increase its ability to trap significant amounts of sediment and other pollutants during wet weather events. The project will also restore open water fisheries habitat in the impoundment behind Singing Dam. Removal of sediment at Singing Dam would, over the long-term, protect valuable fisheries and wildlife habitat at Fisherville Pond and at other downstream sites.

Wetlands restoration project alternatives are presented for the 41-acre Lonsdale Drive-In site located along the Blackstone River in Lincoln, Rhode Island. Two alternatives are presented to restore the former Drive-In and enhance fisheries and wildlife habitat. Alternative 1 involves the removal of the bituminous concrete and gravel base of the former Drive-In to create about 15 acres of emergent marsh and open water habitat. Existing forested riparian habitat along the river would be preserved as much as possible. The estimated cost of Alternative 1 is $2,100,000. Alternative 2 would involve the creation of about 22 acres of grassland habitat with no restored wetland habitat. The estimated cost of Alternative 2 is $1,250,000.

The Reconnaissance investigation also identifies the restoration of anadromous fish as a goal for the Blackstone River watershed. Federal and State fisheries agencies have identified the need to construct fish passage facilities at the lower four dams to gain access to the first significant habitat area at Valley Falls Pond. The Corps provided funding to USFWS as part of this study to develop preliminary designs and cost estimates at these dams. The costs for providing both upstream and downstream fish passage facilities are $910,000, $245,000, $595,000, and $455,000 for Main Street Dam, Slater Mill Dam, Elizabeth Webbing Mill Dam, and Valley Falls Dam, respectively. The present worth of O&M and monitoring at the four projects is an additional $148,000.

In addition to the above described projects, the investigation also provides preliminary designs and cost estimates for a habitat restoration project at the former Rockdale Pond site in Northbridge, Massachusetts ($1,730,000), a wetlands restoration project at a gravel pit in Northbridge, Massachusetts ($581,000), a habitat restoration project at Rice City Pond in Uxbridge, Massachusetts ($4,580,000) and a stream restoration project at Beaver Brook in Worcester, Massachusetts ($2,780,000).

The Reconnaissance investigation has clearly established a Federal interest in the Blackstone River watershed to address the ecosystems' degraded functions and values consistent with the Corps budget guidance and EC 1105-2-210. The identified degradation in the Blackstone River watershed has resulted in the loss of a historic anadromous fishery, degraded resident fisheries, degraded and insufficient waterfowl habitat, degraded benthic macroinvertebrate communities, and lost or degraded wetland, instream and riparian habitat. Implementation of the watershed restoration projects presented would result in a significant positive impact on the ecological health of the watershed. However, the construction of these projects does not represent the full extent of work required to fully restore degraded ecological conditions in the watershed. Construction of similar projects throughout the study area would be required to achieve the highest level of improvement. This Reconnaissance investigation identifies the need for a comprehensive analysis of the problems and opportunities of the entire watershed, including an assessment of the opportunities offered by each sub-basin, to develop and prioritize additional restoration projects in the watershed. These studies would be conducted as part of future Corps of Engineers Feasibility Investigations. The Feasibility Investigation would also refine the preliminary restoration plans for the projects presented in this report and identify potential Corps implementation of additional restoration projects in the watershed.

X. RECOMMENDATIONS

Based on the findings documented in this Reconnaissance investigation, the presence of Corps flood damage reduction projects in the watershed, and the Congressional designation of the region as a National Heritage Corridor, I have determined that justification exists for continued Corps of Engineers involvement in the Blackstone River watershed. I recommend that a cost shared feasibility investigation be conducted by the Corps of Engineers and non-Federal sponsors to investigate potential environmental restoration projects in the Blackstone River watershed.

MICHAEL W. PRATT
Lieutenant Colonel, Corps of Engineers
Commanding

APPENDIX A - COST ESTIMATES FOR PROTOTYPE PROJECTS

	QUANTITY UOM	CONTRACT	ESCALATN	CONTINGN	E&D	CONST.M.	TOTAL COST	UNIT COST
01 Blackstone River Recon								
01.01 Fisherville Pond - Alt.1								
01.01.01 Excavation		48,498	3,215	10,343	3,723	3,947	69,726	
01.01.02 Access Road		196,079	12,999	41,816	15,054	15,957	281,904	
01.01.03 Repair Existing Dam		109,697	7,272	23,394	8,422	8,927	157,711	
01.01.04 Repair Sluice Gate		192,151	12,738	40,978	14,752	15,637	276,257	
01.01.05 Buffer Strip/Planting		48,997	3,248	10,449	3,762	3,987	70,444	
01.01.06 Access Bridge		12,958	859	2,763	995	1,055	18,630	
TOTAL Fisherville Pond - Alt.1		608,381	40,331	129,742	46,707	49,510	874,672	
TOTAL Blackstone River Recon		608,381	40,331	129,742	46,707	49,510	874,672	
TOTAL Blackstone River Study		608,381	40,331	129,742	46,707	49,510	874,672	

	QUANTITY UOM	CONTRACT	ESCALATN	CONTINGN	E&D	CONST.M.	TOTAL COST	UNIT COST
01 Blackstone River Recon								
01.02 Fisherville Pond - Alt.2A								
01.02.01 Excavation		24,546	1,627	5,235	1,884	1,998	35,290	
01.02.02 Access Road		193,025	12,796	41,164	14,819	15,708	277,512	
01.02.03 Repair Existing Dam		98,628	6,538	21,033	7,572	8,026	141,797	
01.02.04 Soil sampling and testing		115,391	7,650	24,608	8,859	9,390	165,898	
01.02.05 Access Bridge		12,918	856	2,755	992	1,051	18,572	
01.02.06 Repair Sluice Gate		191,555	12,699	40,851	14,706	15,589	275,400	
01.02.07 Buffer Strip/Planting		48,839	3,238	10,415	3,749	3,974	70,216	
01.02.08 Planting in the habitat		122,595	8,127	26,145	9,412	9,977	176,256	
01.02.9A Dredging (no capping)		508,292	33,696	108,398	39,023	41,365	730,773	
TOTAL Fisherville Pond - Alt.2A		1,315,789	87,227	280,603	101,017	107,078	1,891,715	
TOTAL Blackstone River Recon		1,315,789	87,227	280,603	101,017	107,078	1,891,715	
TOTAL Blackstone River Study		1,315,789	87,227	280,603	101,017	107,078	1,891,715	

	QUANTITY UOM	CONTRACT	ESCALATN	CONTINGN	E&D	CONST.M.	TOTAL COST	UNIT COST
01 Blackstone River Recon								
01.02 Fisherville Pond - Alt.2B								
01.02.01 Excavation		24,518	1,625	5,229	1,882	1,995	35,249	
01.02.02 Access Road		192,803	12,781	41,117	14,802	15,690	277,193	
01.02.03 Repair Existing Dam		98,514	6,531	21,009	7,563	8,017	141,634	
01.02.04 Soil sampling and testing		115,259	7,641	24,580	8,849	9,380	165,708	
01.02.05 Access Bridge		12,903	855	2,752	991	1,050	18,551	
01.02.06 Repair Sluice Gate		191,335	12,684	40,804	14,689	15,571	275,084	
01.02.07 Buffer Strip/Planting		48,783	3,234	10,403	3,745	3,970	70,135	
01.02.08 Planting in the habitat		122,455	8,118	26,114	9,401	9,965	176,053	
01.02.9B Dredging (1' Cap)		1,507,297	99,923	321,444	115,720	122,663	2,167,047	
TOTAL Fisherville Pond - Alt.2B		2,313,866	153,392	493,452	177,643	188,301	3,326,654	
TOTAL Blackstone River Recon		2,313,866	153,392	493,452	177,643	188,301	3,326,654	
TOTAL Blackstone River Study		2,313,866	153,392	493,452	177,643	188,301	3,326,654	

	QUANTITY UOM	CONTRACT	ESCALATN	CONTINGN	E&D	CONST.M.	TOTAL COST	UNIT COST
01 Blackstone River Recon								
01.02 Fisherville Pond - Alt.2C								
01.02.01 Excavation		24,471	1,622	5,219	1,879	1,991	35,183	
01.02.02 Access Road		192,439	12,757	41,039	14,774	15,661	276,670	
01.02.03 Repair Existing Dam		98,328	6,518	20,969	7,549	8,002	141,367	
01.02.04 Soil sampling and testing		115,041	7,626	24,533	8,832	9,362	165,395	
01.02.05 Access Bridge		12,879	854	2,746	989	1,048	18,516	
01.02.06 Repair Sluice Gate		190,974	12,660	40,727	14,662	15,541	274,564	
01.02.07 Buffer Strip/Planting		48,690	3,228	10,384	3,738	3,962	70,002	
01.02.08 Planting in the habitat		122,223	8,103	26,065	9,383	9,946	175,721	
01.02.9C Dredging (2' Cap)		3,837,868	254,423	818,458	294,645	312,324	5,517,717	
TOTAL Fisherville Pond - Alt.2C		4,642,914	307,791	990,141	356,451	377,838	6,675,135	
TOTAL Blackstone River Recon		4,642,914	307,791	990,141	356,451	377,838	6,675,135	
TOTAL Blackstone River Study		4,642,914	307,791	990,141	356,451	377,838	6,675,135	

U.S. Army Corps of Engineers
PROJECT BLACKS: Blackstone River Study - Recon. Study Preliminary cost
Preliminary Estimate
** PROJECT OWNER SUMMARY - Subfeat **

	QUANTITY UOM	CONTRACT	ESCALATN	CONTINGN	E&D	CONST.M.	TOTAL COST	UNIT COST
01 Blackstone River Recon								
01.03 Singing Dam								
01.03.01 Excavation		980,291	64,986	209,055	75,260	79,776	1,409,369	
01.03.02 Access road		146,102	9,686	31,158	11,217	11,890	210,052	
01.03.03 Install Gate		446,547	29,603	95,230	34,283	36,340	642,002	
01.03.04 Soil testing		90,419	5,994	19,283	6,942	7,358	129,995	
01.03.05 Disposal facility		358,093	23,739	76,366	27,492	29,141	514,832	
TOTAL Singing Dam		2,021,452	134,008	431,092	155,193	164,505	2,906,249	
TOTAL Blackstone River Recon		2,021,452	134,008	431,092	155,193	164,505	2,906,249	
TOTAL Blackstone River Study		2,021,452	134,008	431,092	155,193	164,505	2,906,249	

	QUANTITY UOM	CONTRACT	ESCALATN	CONTINGN	E&D	CONST.M.	TOTAL COST	UNIT COST
01 Blackstone River Recon								
01.04 Beaver Brook								
01.04.01 Excavation		850,002	56,349	181,270	65,257	69,173	1,222,051	
01.04.02 Demolition - Steel Arch		476,049	31,559	101,522	36,548	38,741	684,418	
01.04.03 Place - Rock deflectors		2,527	168	539	194	206	3,633	
01.04.04 Place - Gravel Bedding		82,116	5,444	17,512	6,304	6,683	118,058	
01.04.05 Place - Stone Protection		183,811	12,185	39,199	14,112	14,958	264,266	
01.04.06 Place - Top Soil		55,374	3,671	11,809	4,251	4,506	79,611	
01.04.07 Planting		125,073	8,291	26,673	9,602	10,178	179,817	
01.04.08 Clear and Grubbing		130,843	8,674	27,903	10,045	10,648	188,114	
TOTAL Beaver Brook		1,905,795	126,340	406,427	146,314	155,093	2,739,969	
TOTAL Blackstone River Recon		1,905,795	126,340	406,427	146,314	155,093	2,739,969	
TOTAL Blackstone River Study		1,905,795	126,340	406,427	146,314	155,093	2,739,969	

	QUANTITY UOM	CONTRACT	ESCALATN	CONTINGN	E&D	CONST.M.	TOTAL COST	UNIT COST
01 Blackstone River Recon								
01.05 Former Rockdale Pond - COZ								
01.05.01 Excavation		78,843	5,227	16,814	6,053	6,416	113,352	
01.05.02 Access Road		20,354	1,349	4,341	1,563	1,656	29,263	
01.05.03 Gravel Bedding		38,446	2,549	8,199	2,952	3,129	55,274	
01.05.04 Stone Protection		69,525	4,609	14,827	5,338	5,658	99,956	
01.05.05 Glacial till clay		618,361	40,993	131,871	47,474	50,322	889,021	
01.05.06 Top Soil		222,065	14,721	47,357	17,049	18,072	319,264	
01.05.07 Vegetation		105,380	6,986	22,473	8,090	8,576	151,506	
TOTAL Former Rockdale Pond - COZ		1,152,974	76,434	245,882	88,517	93,828	1,657,636	
TOTAL Blackstone River Recon		1,152,974	76,434	245,882	88,517	93,828	1,657,636	
TOTAL Blackstone River Study		1,152,974	76,434	245,882	88,517	93,828	1,657,636	

	QUANTITY UOM	CONTRACT	ESCALATN	CONTINGN	E&D	CONST.M.	TOTAL COST	UNIT COST
01 Blackstone River Recon								
01.08 Rice City Pond Dam								
01.08.01 Drain East Pond		671	44	143	52	55	965	
01.08.02 Sheet Pile Installation		1,587,455	105,237	338,538	121,874	129,186	2,282,290	
01.08.03 Earth Embankment Improvements		512,489	33,974	109,293	39,345	41,706	736,807	
01.08.04 Raise Service Spillway		94,839	6,287	20,225	7,281	7,718	136,350	
01.08.05 Raise Secondary Spillway		330,219	21,891	70,422	25,352	26,873	474,756	
01.08.06 Constr. Spillway Retaining Wall		132,226	8,766	28,198	10,151	10,761	190,102	
01.08.07 Replace Canal Gate		446,072	29,571	95,129	34,246	36,301	641,319	
TOTAL Rice City Pond Dam		3,103,970	205,771	661,948	238,301	252,599	4,462,590	
TOTAL Blackstone River Recon		3,103,970	205,771	661,948	238,301	252,599	4,462,590	
TOTAL Blackstone River Study		3,103,970	205,771	661,948	238,301	252,599	4,462,590	

	QUANTITY UOM	CONTRACT	ESCALATN	CONTINGN	E&D	CONST.M.	TOTAL COST	UNIT COST
01 Blackstone River Recon								
01.07 Northbridge Gravel Pit								
01.07.01 Excavation		237,232	15,727	50,592	18,213	19,306	341,069	
01.07.02 Place Top Soil		36,877	2,445	7,864	2,831	3,001	53,018	
01.07.03 Planting/Seeding		102,668	6,806	21,895	7,882	8,355	147,606	
TOTAL Northbridge Gravel Pit		376,777	24,978	80,351	28,926	30,662	541,693	
TOTAL Blackstone River Recon		376,777	24,978	80,351	28,926	30,662	541,693	
TOTAL Blackstone River Study		376,777	24,978	80,351	28,926	30,662	541,693	

	QUANTITY UOM	CONTRACT	ESCALATN	CONTINGN	E&D	CONST.M.	TOTAL COST	UNIT COST
01 Blackstone River Recon								
01.06 Lonsdale - Alt.1								
01.06.01 Excavation	170000.00 CY	465,415	30,854	49,627	32,754	34,719	613,369	3.61
01.06.02 Restore Upland Habitat		7,193	477	767	506	537	9,480	
01.06.03 Vegetation	1.00 EA	175,366	11,625	18,699	12,341	13,082	231,114	231114.11
01.06.04 Demolition - Pavement, Posts		150,498	9,977	16,047	10,591	11,227	198,340	
01.06.05 Place top soil	12000.00 CY	305,936	20,281	32,622	21,530	22,822	403,191	33.60
01.06.06 Parking lot	1.00 EA	2,535	168	270	178	189	3,341	3341.33
TOTAL Lonsdale - Alt.1		1,106,944	73,382	118,033	77,902	82,576	1,458,836	
TOTAL Blackstone River Recon		1,106,944	73,382	118,033	77,902	82,576	1,458,836	
TOTAL Blackstone River Study		1,106,944	73,382	118,033	77,902	82,576	1,458,836	

	QUANTITY	UOM	CONTRACT	ESCALATN	CONTINGN	E&D	CONST.M.	TOTAL COST	UNIT COST
01 Blackstone River Recon									
01.6A Lonsdale - Alt.2									
01.6A.01 Demolition - Pavement, Posts			151,144	10,020	16,116	10,637	11,275	199,192	
01.6A.02 Place top soil	12000.00	CY	306,396	20,312	32,671	21,563	22,857	403,798	33.65
01.6A.04 Parking lot (Includes Bumpers)	74.00	CY	2,328	154	248	164	174	3,068	41.46
01.6A.05 Seeding	28000.00	SY	5,968	396	636	420	445	7,866	0.28
TOTAL Lonsdale - Alt.2			465,836	30,882	49,672	32,783	34,750	613,924	
TOTAL Blackstone River Recon			465,836	30,882	49,672	32,783	34,750	613,924	
TOTAL Blackstone River Study			465,836	30,882	49,672	32,783	34,750	613,924	

APPENDIX B - CORRESPONDENCE

BLACKSTONE RIVER VALLEY
National Heritage Corridor Commission

One Depot Square
Woonsocket, RI 02895
Tel 401 762 · 0250
Fax 401 762 · 0530

Mr. Richard D. Reardon, Chief
Engineering/Planning Division
NED, U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

August 21, 1997

Dear Mr. Reardon

The Blackstone River Valley National Heritage Corridor Commission staff has reviewed the draft Blackstone River Watershed Reconnaissance Investigation Report. A more detailed response regarding Section 106 of the National Historic Preservation Act of 1966, as amended, will be drafted under a separate cover. We commend the U. S. Army Corps of Engineers, and in particular John Kennelly and Bill Mullen, for your efforts in bringing together a diverse group of interested citizens, private organizations and state and Federal agencies to address a very difficult issue -- the restoration of the Blackstone River.

The Blackstone River Valley National Heritage Corridor was created by Congress in 1986 (P.L. 99-647). A twenty member, bi-state Federal Commission was established to preserve and interpret, for the educational and inspirational benefit of present and future generations, the unique and significant contributions to our national heritage of certain historic and cultural lands, waterways and structures within the Blackstone Valley in the States of Massachusetts and Rhode Island.

The Heritage Corridor Commission has been very much involved with the facilitation and coordination of environmental issues throughout the Blackstone Valley. The Commission has supported the watershed planning efforts of both the states of Rhode Island and Massachusetts, EPA, FEMA, Save the Bay, Massachusetts Audubon, and others on studies that address water quality, water quantity, and land use. The Commission, through its Environmental Sub-Committee, supported the Army Corps State(s) Planning Assistance report produced in 1992 outlining a comprehensive plan to restore the river.

The draft Blackstone River Watershed Reconnaissance Investigation examined the ecosystem of the Blackstone River watershed and found, as did many other studies, significant ecological problems. The investigation also recommends potential solutions and cost estimates that would significantly improve the health of the river system. The Commission supports the study's recommended "modeling" approach to addressing key environmental issues. I am sure that by implementing select demonstration projects, we will learn an incredible amount of information that can be transferred to other restoration sites throughout the Blackstone Valley.

We also appreciate the scale and magnitude of the proposed projects and suggest that the Corps maintain and expand its working relationships with other Federal agencies, the states of Rhode Island and Massachusetts, local governments and private organizations to ensure that the effects of one action do not adversely affect those of another. As you are aware, we need to find consensus and a balance among the various interests relating to river restoration, historic preservation, recreation and economic development.

In December, the Corridor Commission will be submitting an application for designation as an "American Heritage River", as announced by President Clinton in his State of the Union address. The recommendations of this study is just the type of coordinated and focused Federal/State assistance that is needed to restore the Blackstone Watershed. We look forward to working with the Army Corps on the next phase of implementation of these findings.

Sincerely,

for Susan Moore
Executive Director

cc: Executive Committee, Blackstone River Valley National Heritage Corridor Commission
Chair, Environmental Sub-Committee, BRVNHC
Massachusetts Congressional Delegation
Rhode Island Congressional Delegation

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New England Field Office
22 Bridge Street, Unit #1
Concord, New Hampshire 03301-4986

August 19, 1997

Richard D. Reardon
Engineering/Planning Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, Ma 02254-9149

Dear Mr. Reardon:

This responds to your July 18, 1997 cover letter and accompanying draft Blackstone River Watershed Reconnaissance Investigation Report. We have reviewed the draft report and offer the following comments.

We support the work the Corps is performing regarding the identification of potential habitat restoration projects within the Blackstone River watershed. While we have no concerns with the process, per se, we do have concerns with some of the representative projects detailed in the report. We realize that at this stage these projects are primarily to be used as examples of possible measures that would benefit fish and wildlife within the watershed, however during the feasibility phase one or more of these projects may be targeted for implementation. During project selection we foresee having significant input as to the pros and cons of each activity investigated.

Staff from this office are currently on the technical advisory committee. We hope to continue to participate as the Corps moves into the feasibility phase, perhaps as a member of the study management team. We believe our continued involvement will afford us the opportunity to voice any concerns we may have as the process proceeds.

Thank you for this opportunity to comment. If you have any questions, please contact Melissa Grader of this office at (413) 863-9475, ext 20.

Sincerely yours,

Michael J. Bartlett
Supervisor

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New England Field Office
22 Bridge Street, Unit #1
Concord, New Hampshire 03301-4986

July 23, 1997

Richard D. Reardon
Engineering/Planning Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Dear Mr. Reardon:

This responds to your June 18, 1997 letter requesting information on the presence of federally-listed and proposed endangered or threatened species in relation to the Corps Reconnaissance Investigation focused on environmental restoration needs and opportunities in the Blackstone River watershed in Rhode Island and Massachusetts. The following comments are also provided in accordance with the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.).

Based on information currently available to us, only one federally-listed, threatened species under the jurisdiction of the U.S. Fish and Wildlife Service is known to occur in the project area, the small whorled pogonia (*Isotria medeoloides*). The small whorled pogonia, an orchid, is found in the town of Glocester, Rhode Island. Occasional wintering or transient threatened bald eagles (*Haliaeetus leucocephalus*) and endangered peregrine falcons (*Falco peregrinus anatum*) may also periodically occur in the watershed. The banded bog skimmer (*Williamsonia linteri*) is also found at a number of sites in both Massachusetts and Rhode Island in the Blackstone River watershed. This is a former category 2 species that has the potential to become listed as threatened or endangered in the future. We suggest that you contact Rick Enser of the Rhode Island Natural Heritage Program, 235 Promenade Ave., Rhode Island 02903, at 401-277-2776, for further site-specific information on these and state-listed species that may be present.

Preparation of a Biological Assessment or further consultation with us under Section 7 of the Endangered Species Act may be required depending on the nature of activities planned. A list of federally-designated endangered species in Rhode Island is enclosed for your information.

We encourage all efforts by the Corps to identify and develop plans for restoration opportunities in the Blackstone River watershed. The Rhode Island Habitat Restoration Team is always looking for good restoration projects. The Team, which is composed of habitat restoration experts from numerous agencies and groups, has a goal of restoring fish and wildlife habitat in Rhode Island. We agree that priority should be given to projects which restore degraded ecosystem functions and values. An example of this type of project identified in your study is the old Lonsdale Drive-In site. Currently, the Department of the Interior is working with RIDEM to purchase this land. Funds from the settlement at the Landfill and Recovery Superfund Site in North Smithfield are earmarked for this project. We recommend that this site receive a high priority for restoration funding.

The 41-acre Lonsdale Drive-In site has excellent restoration potential for fish and wildlife habitat. Most of the site is located in the 100-year floodplain of the Blackstone River. Restoration would involve removing the old structures and pavement from approximately 22 acres. Many factors should be considered in the design of this restoration. We prefer an alternative similar to your Alternative 1 where one large depressional basin is created. This would allow development of a mosaic of different wetland types. Three types of habitat could be established in the depressional basin. The innermost part of the basin could be open water. This will provide an important staging area for migratory waterfowl. The next zone could be an emergent wetland that transitions to a meadow or scrub/shrub wetland. The final grading of the site should be undulating in order to create hummocky microtopography. Tree stumps could also be used to help create hummocks.

It is important to understand the groundwater hydrology of the site before we develop final plans. At least one year of groundwater monitoring is needed. The bottom elevations of the different habitat types need to be set according to seasonal groundwater elevations. The 25-foot-wide flow channel at the northeast corner of the site that currently allows entrance of water on storm events could be widened and deepened to increase flooding of the site. Enhancement of the channel would also provide the potential for anadromous fish spawning in the wetlands.

We agree that the existing forested riparian habitat along the river should be preserved. We recommend that the perimeter of the site should be forested to isolate it from the surrounding roads and development. The large trees on slopes along the western part of the property should remain. The adjacent Lonsdale marsh could be used as a reference site. One foot of organic soil or a good substitute is needed to provide a good base for wetland development. At a minimum, a Phase I hazardous materials survey should be completed for the project site.

Please contact Greg Mannesto of our Rhode Island Office at (401) 364-9124 if we can be of further assistance.

Sincerely yours,

Michael Amaral

Michael J. Amaral
Acting Supervisor
New England Field Office

Enclosure

FEDERALLY LISTED ENDANGERED AND THREATENED SPECIES IN RHODE ISLAND

Common Name	Scientific Name	Status	Distribution
FISHES:			
Sturgeon, shortnose*	Acipenser brevirostrum	E	Atlantic coastal waters and rivers
REPTILES:			
Turtle, green*	Chelonia mydas	T	Oceanic straggler in southern New England
Turtle, hawksbill*	Eretmochelys imbricata	E	Oceanic straggler in southern New England
Turtle, leatherback*	Dermochelys coriacea	E	Oceanic summer resident
Turtle, loggerhead*	Caretta caretta	T	Oceanic summer resident
Turtle, Atlantic ridley*	Lepidochelys kempii	E	Oceanic summer resident
BIRDS:			
Eagle, bald	Haliaeetus leucocephalus	T	Entire state, occasional
Falcon, American peregrine	Falco peregrinus anatum	E	No current nesting; entire state-migratory
Falcon, Arctic peregrine	Falco peregrinus tundrius	T	No nesting; entire state-migratory
Plover, Piping	Charadrius melodus	T	Atlantic coast, Washington and Newport Counties
Roseate Tern	Sterna dougallii dougallii	E	Atlantic coast
MAMMALS:			
Whale, blue*	Balaenoptera musculus	E	Oceanic
Whale, finback*	Balaenoptera physalus	E	Oceanic
Whale, humpback*	Megaptera novaeangliae	E	Oceanic
Whale, right*	Eubalaena spp. (all species)	E	Oceanic
Whale, sei*	Balaenoptera borealis	E	Oceanic
Whale, sperm*	Physeter catodon	E	Oceanic
MOLLUSKS:			
NONE			
INSECTS:			
Beetle, American burying	Nicrophorus americanus	E	Washington
Beetle, northeastern beach tiger	Cicindela dorsalis dorsalis	T	Washington, extirpated
PLANTS:			
Small Whorled Pogonia	Isotria medeoloides	T	Providence, Kent Counties
Gerardia, Sandplain	Agalinus acuta	E	Washington

* Except for sea turtle nesting habitat, principal responsibility for these species is vested with the National Marine Fisheries Service

Rev. 4-17-97

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION I
JOHN F. KENNEDY FEDERAL BUILDING
BOSTON, MASSACHUSETTS 02203-0001

August 21, 1997

Richard D. Reardon, P.E., Chief
Engineering/Planning Division
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

Dear Mr. Reardon:

Thank you for the opportunity to review the Blackstone River Watershed Reconnaissance Investigation Report. We are excited about the types of projects being proposed and the potential to complement the regulatory agencies efforts to control point and nonpoint sources of pollution. In particular, habitat restoration, fish passage improvement, management of contaminated sediments, and stabilization of eroding streambanks are critical activities that, when combined with the control of pollution sources, should enhance attainment of the Clean Water Act goals.

We continue to be concerned with the highly contaminated sediments in many of the impoundments and encourage the COE to make sediment remediation a high priority. The lack of significant numbers of pollution intollerant fish species further supports the need to address the toxic sediments.

We have the following project specific comments:

The Londsdale project discussed restoring 7 acres of grassland habitat. There should be some discussion as to the habitat benefits relative to the habitat needs of grassland bird species. Several grassland bird species require significantly larger acreage.

There are NPDES discharges downstream of the COE flood control bypass in Worcester. Any increase in the bypass volume could reduce the assimilative capacity of the river in the vicinity of these discharges. It may be possible to operate under high flow conditions only and incorporate a sediment control basin as part of the ongoing effort by the City of Worcester to control stormwater pollutant loads.

We would like to see a greater emphasis on evaluating the feasibility of removing dams. Concerns with the downstream transport of contaminants could be addressed through a combination of dredging and stabilization measures. Consideration should be given to developing an economic analysis of the value of a free flowing river versus the value of hydropower generation. Any review of historical significance would ideally consider the historical significance of a free flowing anadromous fishery.

If you have any questions, please contact David Pincumbe of my staff at (617) 565-4429.

Sincerely,

Jane Downing

Jane Downing, Director
MA Office of Ecosystem Protection

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Habitat and Protected
Resources Division
James J. Howard Marine
Sciences Laboratory
Highlands, New Jersey 07732

August 21, 1997

Mr. Richard D. Reardon
Engineering/Planning Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Dear Mr. Reardon:

This is in response to your July 28, 1997 request for comments on the draft ***Blackstone River Watershed Reconnaissance Investigation Report***. The Blackstone River Valley reconnaissance effort includes shore stabilization, contaminated sediment remediation and mitigation of obstructions to anadromous fish passage due to the historic construction of dams, and we support the initiative.

For half a century, the Blackstone River has been a significant source of pollutant discharge to the tidally influenced waters of Narragansett Bay. Long term industrial and residential uses (such as the disposal of untreated sewage and chemical discharges), combined with the construction of over 30 low head water diversion dams, culminated in massive destruction of aquatic habitat and a precipitous decline in fishery resources including migratory clupeids such as shad and other river herring. Even today, contaminated river bottom and streambank sediments are a persistent source of pollution to the Blackstone River Valley.

The reconnaissance initiative strives to integrate the efforts of Federal and State partners to restore the ecological integrity of the watershed. We support several of the initiative's abatement strategies including:

- the remediation of contaminated sediment resuspension through removal and environmentally sound disposal
- the use of state-of-the-art bio-engineering techniques for sediment and bank stabilization
- dam repair and mitigation of effects

- planned removal of impediments to upstream and downstream fish migration
- the construction of fish passage facilities
- the restoration of fish and wildlife habitat

If you wish to discuss this matter further, please contact Ms. Cori M. Rose at (203) 783-4228.

Sincerely,

Stanley W. Gorski
Field Offices Supervisor

cc:
NED - Waltham, MA (M. Penko)
ST/FD - Gloucester, MA (K. Beal)
HPR - Gloucester, MA (E. Hutchins)

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

HISTORICAL PRESERVATION & HERITAGE COMMISSION

Old State House • 150 Benefit Street • Providence, R.I. 02903-1209

Preservation (401) 277-2678 FAX (401) 277-2968
Heritage (401) 277-2669 TDD (401) 277-3700

August 13, 1997

Mr. Richard D. Reardon
Chief
Engineering/Planning Division
NED, U. S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

RE: Reconnaissance Investigation
Blackstone River Watershed

Dear Mr. Reardon:

The Rhode Island Historical Preservation and Heritage Commission staff has reviewed the package of information you have provided on the U. S. Army Corps of Engineers' study of potential environmental restoration projects in the Blackstone River Valley. We understand that the Corps has identified two such projects in Rhode Island: the Lonsdale Drive-In wetland restoration and the provision for fish passage at the four most downstream dams on the Blackstone River. We have the following comments on these prospective undertakings.

Lonsdale Drive-In Wetland Restoration - The area proposed for restoration abuts the Lonsdale National Register Historic District in Lincoln and Cumberland and historically it was used as a company farm by the Lonsdale Corporation. It appears that the either restoration alternative would be compatible with the adjacent historic setting and result in no adverse effect to the Historic District.

Fish Passages, Pawtucket, Central Falls & Cumberland - The four locations under study for the installation of fish ladders are sensitive for the historical quality of the dams and the associated industrial buildings and sites. The Slater Mill Dam and the Central Falls Dam are listed on the National Register of Historic Places as elements of the Slater Mill Historic Site and Central Falls Mill Historic District, respectively. The Pawtucket Falls (Main Street) Dam and the Valley Falls Dam are both associated with historic industrial complexes listed on the National Register (Bridge Mill Power Plant and Valley Falls Mill, respectively) and are potentially eligible for listing on the National Register.

It appears from the preliminary designs that the Denil fishways proposed for installation at these dams will be physically and visually intrusive and detract from the dams' historic appearance. This would result in a finding of adverse effect at each dam.

Given these potential adverse effects, it will be important to determine what alternatives to the preliminary designs may exist. Alternative routes that avoid direct effects to the dam or measures that could reduce the physical and visual impact of the fishways should be investigated.

The RIHP&HC staff is prepared to work with you on this investigation to insure that the Section 106 issues are appropriately resolved. Please contact Richard E. Greenwood, Project Review Coordinator of this office if you have any questions.

Yours very truly,

Edward F. Sanderson
Executive Director
Deputy State Historic
Preservation Officer

cc: Michael Creasey, BRVNHCC

(T:77)

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02254-9149

REPLY TO
ATTENTION OF

July 10, 1997

RECEIVED
JUL 14 1997
MASS. HIST. COMM.
17??

Engineering/Planning Division
Evaluation Branch

CONCURRENCE: Judith B. McDonough
JUDITH B. McDONOUGH
STATE HISTORIC
PRESERVATION OFFICER
MASSACHUSETTS
HISTORICAL COMMISSION

Ms. Judith McDonough, Executive Director
Massachusetts Historical Commission
The Massachusetts State Archives Building
220 Morrissey Boulevard
Boston, Massachusetts 02125

Dear Ms. McDonough:

The U.S. Army Corps of Engineers, New England District, is conducting a Reconnaissance Investigation focused on environmental restoration needs and opportunities in the Blackstone River watershed in Rhode Island and Massachusetts (see enclosed maps and draft plans). We would like your comments on the following undertaking as per Section 106 of the National Historic Preservation Act of 1966, as amended and implementing regulations 36 CFR 800.

The study will provide an overview of the environmental problems and needs of the watershed and identify a number of potential Corps projects to address these needs. Based on nationwide Corps policy guidance, priority is given to projects that restore degraded ecosystem functions and values. Restoration opportunities that improve fish and wildlife habitat quality by modifying hydrology or substrate are considered most appropriate for Corps involvement.

The Blackstone River begins in the southern part of Worcester, Massachusetts, and flows southeasterly for 46 miles to the Main St. Dam in Pawtucket, Rhode Island, where it becomes the tidal Seekonk River. The Blackstone River watershed covers an area of 475 square miles, with 335 square miles in south central Massachusetts and 140 square miles in northern Rhode Island (see enclosed map).

Based on preliminary coordination with Federal and State agencies, and other interested organizations, principal ecological problems of the watershed include: the loss or degradation of wetland, stream, and riparian habitat due to development (including Corps flood control projects), poor sediment quality in impoundments, loss of anadromous fish passage due to dams, poor water quality, colonization by invasive non-native species (e.g. purple loosestrife), flow fluctuations on the Blackstone River thought to be caused by hydropower operations, risk of habitat loss and sediment release due to dam failure, and the export of nutrients and contaminants from the Blackstone River watershed to Narragansett Bay.

Our reconnaissance study identified various types of environmental restoration projects appropriate for Corps implementation in the Blackstone River watershed. Conceptual site-specific restoration plans were developed for selected locations to demonstrate the application of various types of restoration measures and to determine the approximate cost of the projects. We envision that future studies will identify additional sites where these types of projects are applicable. The sites included in the reconnaissance investigation include from upriver to downriver: restoration of stream habitat at Beaver Brook, Worcester, Massachusetts; dredging a portion of the Singing Dam impoundment to create a sediment capture pond in Sutton, Massachusetts; restoration of aquatic and waterfowl habitat at Fisherville Pond, Grafton, Massachusetts; restoration of riparian habitat at the former Rockdale Impoundment, Grafton, Massachusetts; restoration of a gravel pit in Northbridge, Massachusetts; wetland restoration at the Lonsdale Drive-In, in Lincoln, Rhode Island; and provision for fish passage at the four most downstream dams on the Blackstone River in Rhode Island. Descriptions of these projects, along with preliminary restoration plans, are provided in the enclosure. Additional studies conducted as part of future feasibility-level studies will likely refine the plans presented in this report.

The Blackstone River Valley National Heritage Corridor extends from Worcester, Massachusetts, to Narragansett Bay in Rhode Island. Congress recognized the national significance of the valley through the creation of the Corridor in 1986 to be operated in conjunction with the Secretary of the Interior through the National Park Service, the States of Massachusetts and Rhode Island, and each surrounding community. In addition, a Corridor Commission was established to develop and implement a plan or strategy for historic preservation and interpretation. Congress established this Corridor for the purpose of "preserving and interpreting for the educational and inspirational benefit of present and future generations the unique and significant contributions to our national heritage of certain historic and cultural lands, waterways and structures within the Blackstone River Valley..." (Public Law 99-647, November 10, 1986).

New England District has completed a cultural resources assessment of the proposed study area and alternatives including background research, review of archaeological site files and documentation, and site visits. Hundreds of inventoried historic and archaeological properties are located within both states throughout the study area including historic structures, landscapes, mill complexes, transportation resources, and archaeological remains. Examples of these include the Slater Mill National Historic Site in Pawtucket and the Valley Falls Mill Historic District in Cumberland, both in Rhode Island, the Fisherville Dam Historic District in Grafton, Massachusetts, and the Blackstone Canal National Historic District located in both States. There is also the potential throughout the study area for as yet unidentified and undocumented cultural resources ranging from early Native American occupation to the nineteenth century American Industrial Revolution and the resulting golden age of prosperity.

As project proposals are primarily conceptual in scope, it was not possible to conclusively determine specific impacts upon significant cultural resources. However, due to the significance of the entire valley, it is expected that portions of the proposed work may adversely impact upon significant resources or diminish the characteristics by which these resources were nominated to or may be eligible for, listing on the National Register of Historic Places. For example, the creation of fish passage facilities on the lower four dams in Rhode Island (Main Street, Slater Mill, Elizabeth Webbing/Central Falls, and Valley Falls) could potentially cause an adverse impact upon these resources with the creation of a visually intrusive element not in keeping with the original setting and characteristics by which these resources were deemed significant for National Register listing. Modifications to the dam and surrounding landscape at the Fisherville Historic District could also be considered adverse depending upon the extent of alteration. Likewise, during construction of any of the above proposals, documented and undocumented historic and archaeological resources may be impacted.

However, this is only a preliminary investigation. If this project proceeds to a further stage of planning, then a detailed plan or plans will be selected. At that time, these final plans will be reviewed and a more detailed evaluation of impacts upon cultural resources would be provided together with appropriate methods of mitigation including avoidance, archaeological survey, or documentation prior to implementation. We will request your formal comments on any of these proposals at that time in compliance with Section 106 of the National Historic Preservation Act of 1966, as amended, and implementing regulations 36 CFR 800. Any comments which you may have on the current proposals would be greatly appreciated.

If you have any questions, please contact Mr. Marc Paiva, Archaeologist, of the Evaluation Branch at (617) 647-8796.

Sincerely,

Richard D. Reardon, P.E.
Chief, Engineering/Planning Division

Enclosures

Same Letter Sent:
(See Enclosure)

Same Letter Sent:

(w/enclosures)

Mr. Edward F. Sanderson, Executive Director
Rhode Island Historical Preservation Commission
150 Benefit Street
Providence, Rhode Island 02903

Mr. Michael Creasey, Deputy Director
Blackstone River Valley National Heritage Corridor Commission
One Depot Square
Woonsocket, Rhode Island 02895

Mr. David Clark, Environmental Compliance
National Park Service
Boston Support Office
15 State Street
Boston, Massachusetts 02109

United States Department of the Interior

FISH AND WILDLIFE SERVICE
300 Westgate Center Drive
Hadley, Massachusetts 01035-9589

In Reply Refer To:
FWS/Region-5/BA-EN

March 11, 1997

Mr. William Mullen
New England Division
U. S. Army Corps of Engineers
Planning Division
424 Trapelo Road
Waltham, Massachusetts 02254

Dear Mr. Mullen:

The purpose of this letter is to transmit to your office the enclosed cost estimates for both upstream and downstream fish passage at each of the lowermost 4 barriers on the Blackstone River in Rhode Island that are currently being investigated under your "General Investigation of Environmental Restoration of the Blackstone River Watershed". The conceptual plans for fish passage at each of these four projects have been forwarded under separate cover. These four projects are listed by Federal Energy Regulatory Commission (FERC) file numbers in upstream order as follows:

NAME	FERC #	TYPE
Main Street (Pawtucket 2)	3689	Exemption - 7/21/81
Slater Mill	No Hydro	
Elizabeth Webbing Co.	3037	Order Issuing License 7/13/81
Valley Falls	3063	Order Issuing License 8/28/81

These conceptual plans were initially requested by your office in a letter dated December 12, 1996. A cost estimate for Service engineering staff to complete the conceptual designs was provided by letter dated Jan 2, 1997. On January 9, 1997, we received a formal notice from your office to proceed. The conceptual construction estimate for fishways to pass American shad and river herring upstream and downstream from the dams at the 4 locations is $2,205,000.

If you need any additional information on these cost estimates or the conceptual plans for fish passage at these barriers, please contact Dick Quinn at our Engineering Field Office in Newton Corner, MA. His telephone number is (617) 244-0837.

Sincerely,

David Westerhoff for

Vincent F. Gasbarro
Regional Engineer

Enclosure

cc: M. Grader, USFWS, NEFO(ES)
G. Mannesto, USFWS, RIFO(ES)
J. O'Brien, RIF&W
L. Stolte, CNEAFC

United States Department of the Interior

FISH AND WILDLIFE SERVICE
ONE GATEWAY CENTER, SUITE 700
NEWTON CORNER, MASSACHUSETTS 02158

JUN 13 1990

Colonel Daniel M. Wilson
Division Engineer, NED
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Dear Colonel Wilson:

The North American Wetlands Conservation Act, signed by President Bush on December 13, 1989, calls for the protection, restoration, and management of wetland ecosystems to help achieve the goals and objectives of the North American Waterfowl Management Plan (NAWMP). One of the major purposes of the Act is to encourage partnerships among public agencies and other interests to help achieve wetland conservation goals.

The Massachusetts Division of Fisheries and Wildlife is an active member of the Atlantic Coast Joint Venture under the NAWMP. One of the Division's priority wildlife projects is to restore the marshes associated with Fisherville Pond in Grafton, Massachusetts. Fisherville Pond is at the confluence of the Blackstone and Quinsigamond Rivers. The Fisherville Pond wetlands were once a major state staging and migration area for waterfowl and hosted other species of rare wetland wildlife. The productivity of the wetlands has been essentially lost because the dam gates were opened in 1984, draining the wetlands. The gates were never closed and are no longer functional.

Several conservation partners, including the Division of Fisheries and Wildlife, Ducks Unlimited, the Grafton Forest and Land Trust, the National Park Service, the Town of Grafton, the current landowners, and possibly The Nature Conservancy are committed to help restore the wetlands of this once productive area. We are in great need of engineering and design assistance to make this project a reality, and are seeking the expertise of your office to help in this endeavor. The necessary engineering and design work is estimated to cost approximately $40K.

Preliminary engineering assessments by the Division of Fisheries and Wildlife indicate the dam is structurally sound but corings will be conducted to confirm that assessment. Approximately $7,500 of the $10,000 needed to complete the corings and analysis has already been contributed by project partners. The corings will be completed this year. Funds to actually repair the dam (estimated to be $160,000 - $200,000) will come from another source.

Recognizing the Corps' growing interest in the NAWMP, wetlands restoration engineering, and wetlands initatives in general, the FWS and the Massachusetts Division of Fish and Wildlife would welcome your assistance on this project. We would also welcome the chance to brief you further on project details.

If you have any questions, Dick Dyer of my staff (phone # 617-965-5100 x414) or Wayne McCallum, Director of the Massachusetts Division of Fisheries and Wildlife (phone # 617-727-3151) would be pleased to help. I look forward to hearing from you on perhaps arranging a meeting, and to working with you on this unique partnership in wetland restoration.

Sincerely yours,

Ronald E. Lambertson

Regional Director

J. Kennelly

Kennelly/sdp/78505

August 8, 1996

Planning Directorate
Formulation Division

Mr. Raul Silva
Massachusetts Department of Environmental Management
Office of Dam Safety
100 Cambridge Street, Room 1404
Boston, Massachusetts 02202

Dear Mr. Silva:

The purpose of this letter is to obtain, in writing, the Department of Environmental Management's requirements for the spillway capacity of reconstructed or rehabilitated dams, and in particular the Fisherville Pond Dam located on the Blackstone River in Grafton, Massachusetts.

As you may be aware, the Corps of Engineers is presently conducting a Reconnaissance Investigation of the Blackstone River watershed in Massachusetts and Rhode Island to examine environmental problems in the watershed and to identify potential opportunities for the Corps to address these problems. One of the problems under investigation is the impact of contaminated sediments on the ecological health of the river. These contaminated sediments reside behind the numerous dams on the river, many of which have been classified as High Hazard. In addition, the pool levels of several of these dams have been lowered to minimize the risk of failure, resulting in the loss of valuable waterfowl habitat.

The Corps Reconnaissance study will investigate the Fisherville Pond Dam site to investigate potential measures to address the contaminated sediments and to restore waterfowl habitat. Several alternatives under discussion include the reconstruction of the unsafe, high hazard Fisherville Pond Dam which is presently drained with the outlet gate welded open. The Corps recognizes that rehabilitation of this dam may lead to a more stringent spillway criteria. Conversations with Mr. Frank Terranova of your Lancaster, Massachusetts office have led us to believe that your policy on spillway requirements may vary with the degree (major/minor) of reconstruction. As enlargement of the spillway may significantly impact the cost of rebuilding this dam, we seek clarification of your requirements prior to our formulating a plan of action for Fisherville Pond Dam and other dams in the Blackstone River watershed.

Thank you for your assistance in this matter. Your response to this letter by mid-September 1996 would be greatly appreciated. If you have any questions on this letter, please contact Mr. Bill Mullen, the Corps Reconnaissance Investigation Project Manager, at (617) 647-8559.

Sincerely,

Joseph L. Ignazio
Director of Planning

cc:
Mr. Kennelly, 114S
Ignazio/reading
Reading
FD Files, 114S (SPILLWAY.WP5)

Blackstone Canal Conservancy, Inc.

16 Ballou Road
Hopedale, MA 01747-1833
August 5, 1997

Mr. Mike Penko
Evaluation Branch
Department of the Army
New England District
Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Dear Mr Penko:

Thank you for sending a copy of your draft "Blackstone River Watershed Reconnaissance Investigation". In reading through this, I note several areas that I want to comment on.

First, on page 17, the Mill River is discussed and reported to begin in Milford at North Pond and flow through Worcester to join the Blackstone at Woonsocket. I think someone is confused between the Mill River that starts at North Pond in Milford and flows south through Hopedale & Mendon to reach the Blackstone River in Woonsocket and Mill Brook which is in downtown Worcester and joins with the Middle River to form the Blackstone.

The discussion of Mill Brook on page 16 notes that it is enclosed in conduit for most of its length, but omits that south of Thomas Street and under Harding Street, this conduit is the roofed over Blackstone Canal.

Second, on page 56, you discuss the Blackstone Canal Conservancy and in the third paragraph mention the proposed boat ride in Uxbridge and the "Heritage Homecoming Group". The correct name is Blackstone Valley Heritage Homecoming, Inc. and the animal drawn boat is their project, not the conservancy's. The conservancy is currently working on an less ambitious project to put a boat on the canal at Rice City Pond between the dam and Goat Hill Lock. It is hoped to achieve this in the very near future and use it to educate the public and advance related projects..

Third, I would like to comment on some of the projects the report proposes.

On the plans for Fisherville Pond (**project 6.1**), you correctly show the route of the Blackstone Canal just to the northeast of the P&W Railroad. However, a the west end of the railroad track symbol, the dotted line for the canal joins into a wider flow carrying much of the river's water from the west. This wider flow is also the canal.

On **project 6.3** (Rockdale), Figure 10, on the northeast side of the railroad at about opposite the word "and" in Providence and Worcester Railroad, there is the remains of a Blackstone Canal lock where the canal left the pool behind the former dam. Intact canal then extends northwest along the railroad before curving to cross it where the river and railroad are close to each other at the west edge of the map. A little further northwest, the canal recrosses the railroad and continues intact to Farnumsville. These remains should be protected in any work.

On **project 6.4** (Singing Dam), Figure 11, the northeast bank of the pool is the remains of the canal towpath. At the wooded island, the northeast channel that you plan to improve is the canal. While dredging the channel might help, the essence of these remains need to be preserved in any plan.

Project 6.7 (Raising of Rice City Pond), we are adamantly opposed to the raising of Rice City Pond. At its present level, the canal towpath is above water and much of the Goat Hill Lock is visible. Walks to the lock and discussion of its operation is a major feature of the state park. Canoeing to the lock is also a special treat. Careful inspection of the lock shows that much of the stone missing from the walls is under water in the chamber. This displacement was probably caused by ice and fluctuating water levels when the pond was at its higher level. The lower half of the upstream gates also appear to remain. We are very interested in getting the lock restored and rewatering the canal above to Church Street.

Current efforts are to put a tour boat on this section of the canal. If subsequent efforts to get the lock restored are successful, an appropriate sized craft could lock through and continue from Hartford Ave. to Church St. This would be a trip available no where else in New England.

I think a better proposal might be to use sheet piling and fill to repair the southern five of the six passages between the canal and Rice City Pond and maybe raise the height of the towpath by a few feet. The northern most passage is a historic canal feeder channel and could be bridged. If this occurs, the canal would rise to the level of the southwest spillway and be isolated from the river fluctuations. The towpath would then be available for walking, observing the pond, and even for animals pulling boats.

A further idea, if work is done on the dam, is to install a guard lock of Blackstone Canal size (10' wide x 70' clear) in the dam just to the west of the canal diversion gate. This would allow boat access between the two watered parts of the canal while retaining the flood protection wall.

The conservancy looks forward to cooperative involvement in the improvement of the Blackstone River and preservation of the canal.

Sincerely,

David G. Barber, PE
Treasurer

Copies: Bonnie Brown, MADEM
John Pelczarski, MADEM
Val Stegemoen

Sierra Club

Sierra Club, Rhode Island Chapter
10 Abbott Park Place, 4th Floor
Providence, RI 02903-3735
(401) 521-4734
fax: (401) 331-5266

Mr. Bill Mullen
U.S. Army Corps of Engineers, Planning Division
424 Trapelo Road
Waltham, Mass. 02254-9149

July 12, 1997

RE: Lonsdale Drive-In Wetlands Creation/Restoration, Lincoln, Rhode Island

Dear Mr. Mullen:

As you are probably aware, the Sierra Club Rhode Island Chapter (SCRI) has long been a strong advocate of identifying potential wetland restoration and/or preservation sites within the Blackstone River watershed, which have a high probability of contributing significant ecological functions and societal values. One of our organization's high-priority sites is the defunct Lonsdale Drive-In in Lincoln, Rhode Island, which has favorable conditions for wetland creation/restoration. The SCRI has been supportive of the efforts completed by the Army Corps of Engineers (ACOE) to date on the study of restoration alternatives in the Blackstone River watershed. We have also supported the Rhode Island Department of Environmental Management (RIDEM) work at assessing the value of the drive-in property and negotiating with the owner a possible purchase value and sale. We applaud these efforts and await in great anticipation that this site will eventually be a highly functioning wetland in public ownership.

To assist the ACOE in its studies, the SCRI is presenting the enclosed technical materials on the drive-in site for your review and consideration. We are well aware that the ACOE is completing some initial phase assessments of the site, but it is our organization's objective to identify feasible design alternatives for developing this site into a high value public wetland resource. We are not necessarily supporting a specific design, only pointing out that multiple alternatives are available for consideration. We hope you and your staff will thoroughly review this document and consider them in any subsequent ACOE studies.

Thank you for the opportunity to submit these materials. Should you have any questions regarding these materials, please do not hesitate to contact our office at (401) 521-4734. Our technical people will be glad to discuss these materials with you.

Sincerely,

Liz Vaughn

Liz Vaughn (ske)
Chairperson

cc: M. Penko, ACOE
L. Pointek, RIDEM
R. Enser, RIDEM
J. Coit, Senator Chafee's Office

Protecting America's Environment, For Our Families, For Our Future

Sierra Club Rhode Island Chapter
Conceptual Wetlands Creation/Restoration Design Plan for the Lonsdale Drive-In Site, Lincoln, RI

July 1997

Project Scope

The Lonsdale Drive-In site is located immediately northeast of the intersection of Routes 122 and 123 in the Town of Lincoln, Rhode Island. The site is bordered on the north and east by the Blackstone River and commercial and residential properties to the west and south. The property contains two defunct movie screens, a small building structure, truck trailer, and several debris piles. Much of the site is covered by a thin asphalt layer which once served as parking for the drive-in.

The Sierra Club Rhode Island Chapter (SCRI) envisions that the proposed wetland creation/restoration at the Lonsdale Drive-In site (an area approximately 37 acres in size) will involve the conversion of mostly disturbed uplands with minimal disturbances to upland forest and scrub-shrub wetland. The project would include the removal of asphalt, movie screens and other structures, and sand and gravel to create one or more depressional basins. This creation/restoration area will be hydrologically influenced by both intercepting the regional groundwater table, and capturing storm flows from the Blackstone River. Once excavation has been completed and plantable soils are installed, the site would be seeded and planted with native wetland plant species contributing anticipated ecologic functions. Such a wetland creation/restoration project will result in significant functions including flood storage and flow alteration; multiple cover type wetland complex important as wildlife habitat; and sediment trapping, toxic retention, and nutrient sequestering, uptake, and transformation (denitrification). Societal values would include wildlife viewing and photography, educational activities, and research, and these values could be enhanced if a boardwalk and/or viewing platform were also established.

Existing Site Conditions

1. Site Topography and General Geomorphic Position

Much of the site is located within the highly altered 100-year floodplain of the Blackstone River, which is a lower perennial river discharging to Narragansett Bay. The site is relatively flat, sloping gradually down from the southwest to northeast until reaching the river floodplain berm. Along the western boundary are steep slopes with a change in elevation of as much as 30 to 40 feet. Much of the site is between 50 and 65 feet in elevation, National Geodetic Vertical Datum (ngvd).

2. Soils and Pavement

Lot 54 is underlain by both upland and hydric soils. Limited sampling with a hand-held auger during late April revealed hydric conditions with redoximorphic features present in the upper 12 inches of the soil stratigraphy. The soil was saturated at the surface in a small wetland at the southern end of the lot, which borders John Street. Lot 53 is underlain entirely by upland soils. Lot 52 contains a forest and shrub-dominated wetland in the northeast corner of the parcel along the river. The remainder of the lot is covered with asphalt. Several on-site auger borings to a depth of 33 inches revealed medium-to-coarse sands mixed with cobble-sized rocks. This mixture was uniform throughout the site, and appears to be an altered glacial outwash feature.

The pavement covers approximately 22 acres of the drive-in site, with the asphalt ranging from 0.5 to 1 inch in thickness. This lot also has an earthen berm (A natural floodplain berm affected by grading) running nearly parallel to the river on the eastern side, while a border of large boulders (4-6 feet in diameter) is present along the northern river bank.

Although no contaminated soils were encountered during our limited field sampling, there is concern that contaminated materials may be present on this site. A Phase I hazardous materials survey should be completed for the project site, and it is expected that at least limited Phase II soil sampling and contaminant testing would be required, if it has not already been completed by the owner.

3. Hydrology

Most of the drive-in site is located in the Federal Emergency Management Agency (FEMA) 100-year floodplain, which has been designated as Zone A12 with an 100-year flood elevation of 63 feet ngvd (Refer to FEMA map Panel 445400 0003B, dated August 1982). The site has been flooded on at least several occasions during the last decade, and a narrow (about 25-feet wide) flow channel at the northeast peninsula of the property facilitates entry of smaller-sized storm events. We expect that this overbank river flooding would help to support a hydrology for the wetland creation/restoration. The existing flow channel could enhanced (widened, deepened, and stabilized with riprap or revet matress) to increase flooding of smaller storm events (and enhance the opportunity of temporary flood storage of the wetland).

Surface runoff from Routes 123 and 122 to the south and west, respectively, will provide a minor hydrologic source during storm events. It would be preferable that the -first flush- of runoff (first one inch from impervious surface) be treated by best management practices (e.g., grassed swales, retention pond) prior to discharging to the wetland creation/restoration.

During non-flood periods, the presence of the groundwater, which is dominated by the nearby river elevations, will be the principal hydrology sustaining the wetland creation/restoration. Groundwater monitoring wells should be installed in transacts across the site (in both north-south and west-east directions) to more accurately identify the hydraulic gradient of this site. It is expected that the groundwater fluctuations will closely follow the river elevations, since many of the underlying soils are coarse-grained, highly permeable materials. Monitoring should be completed throughout the site for at least one full growing season to provide important information on the groundwater hydrology.

4. Vegetative Community

The site contains two types of vegetative communities: wetland and upland. Most of the site is uplands. The two areas that currently contain wetlands are the peninsula in the northeast portion of the property and an area on the southeast side of the site bordering Route 123. The dominant tree species in the wetland are American elm (Ulmus americana) and gray birch (Betula populifolia). Other tree species include northern red oak (Quercus rubra), green ash (Fraxinus pennsylvanica), trembling aspen (Populus tremuloides), sycamore (Platanus occidentalis), white pine (Pinus strobus), and silver maple (Acer saccharinum). The shrub layer includes species such as silky dogwood (Cornus amomum), northern arrowwood (Viburnum recognitum), swamp rose (Rosa palustris), and buttonbush (Cephalanthus occidentalis), while skunk cabbage (Symplocarpus foetidus), rough-stemmed goldenrod (Solidago rugosa), reed canary grass (Phalaris arundinacea), rice-cutgrass (Leersia oryzoides), and poison ivy (Toxicodendron radicans) are present in the herb layer.

Larger specimen trees are found on the slopes along the western portion of the property, serving as an important vegetative buffer between the site and nearby urban development.

5. Other Site Features

There are several remnant structures at the drive-in site. There are two large movie screens that are unstable and in disrepair. An old metal box trailer is located on the eastern side of the property along the river. A pile of sand and broken asphalt is located 120 feet north of this trailer. A small, brown wooden structure apparently used once as a power source for the drive-in is located on the western side in Lot 53.

There are two on-site concrete structures. The first was used as the entrance to the drive-in. The second was a concession stand at the northern end of the property. There are also two earthen berms. One is located parallel to the river on the eastern side in Lot 55. The second is in Lot 54 near the river. In addition, there is an area of large-sized boulders along the northern edge of the property. A granite survey boundary marker, marked #6, is located 11 feet inland from the river edge on the northern property riverbank. This survey marker may have been used to complete the FEMA floodplain survey. There is a 6-foot high chain linked fence approximately a 190 feet long separating the asphalt and a field on the western side of the site. Lastly, a metal tower approximately 200 feet in height is located at the center of the drive-in.

Former Site Conditions

1939 Aerial Photographic Interpretation

Aerial photographs taken in 1939 depict the site prior to its development as a drive-in. The original photos were taken at a scale of 1,200:1, although they have since been enlarged to 600:1 scale. The photos reveal that the site was much different in 1939, with most of the site formerly agricultural field. There is evidence of cultivated rows in the photos. It is not possible to determine how much of the site may have wetlands prior to agriculture development. Some of the farmed area may have been hydric soils, although no distinct hydrologic signatures in the soils are discernable from the photos.

Based on the photo interpretation, the site appears to have been divided into two portions. The first portion contained Lots 54, 53, and most of 52, while the second portion began just right of the screen along the northeast peninsula in the river. The photos also reveal that there was much less commercial and residential property around the site. A barn was located at the southern entrance to the drive-in. In addition, there were other farm structures to the southwest of the site. Areas northwest and south of the site also contained agriculture. There was evidence of erosion and flooding (flow channels) at the northwestern end of the site and in the southern portion of the eastern peninsula. This may explain why large stone was more recently placed along the northern property boundary.

Wetland Creation/Restoration Design Alternatives

1. Single Large Basin

A single, large basin (20+ acres) alternative is first considered for wetland creation/restoration. A surface connection to the river would be located at the northeast corner of the property (at the existing channel inlet location), while a constricted outlet (possibly a weir with removable flashboards for hydrologic manipulation) would be located in the southeastern property corner, releasing storm flows back to the river. The basin bottom elevation would be set according to seasonal groundwater elevations, and would be based on the results of the groundwater monitoring.

The basin bottom should not necessarily be graded flat. Rather, small hummocks should be created to increase microtopography at the site. Stumps could also be used to provide structure to increase wildlife habitat cover. The basin would be final graded with a minimum 12-inch thick layer of plantable soils (preferable topsoils with an organic matter content of 5-10 percent) free of large stones and other debris.

Such a basin could include a zonation of three vegetative and open water cover types, depending on the created hydrogeomorphic conditions. The site would be designed and planted to establish forested wetlands along much of the proposed wetland perimeter, although areas of uplands would also be created. This cover type could include planting of species such as red maple, silver maple, sycamore, pin oak (Quercus palustris), American elm, black gum (Nyssa sylvatica), trembling aspen, and gray birch on slopes of 5 percent of less and with a temporary to seasonally flooded/saturated hydrology. Shrub plantings (e.g., silky dogwood, northern arrowhead [Viburnum recognitum]), and seeding of wetland herbaceous species (e.g., deer-tongue grass [Dichanthelium spp.], redtop [Agrostis alba], switchgrass [Panicum virgatum]) would also occur in this zone.

A scrub-shrub wetland could be developed within the limits of the forested wetland and at a slightly lower and wetter elevation (seasonally flooded, saturated to semi-permanently saturated hydrology) influenced by groundwater levels. Plantings could include smooth alder (Alnus serrulata), pussy willow (Salix discolor), other willows (Salix spp.), highbush blueberry (Vaccinium corymbosum), sweet pepperbush (Clethra alnifolia), northern arrowwood, winterberry (Ilex verticillata), and elderberry (Sambucus canadensis).

Still lower in elevation than the shrub-dominant zone would be a mosaic of emergent marsh and open water habitat with a semi-permanent to permanently flooded zone providing an important staging area for waterfowl and feeding and cover area for wading birds and other wildlife. This zone would be dominated by species such as fowl-manna grass (Glyceria canadensis), tussock sedge (Carex stricta), pickerelweed (Pontederia cordata), and duck potato (Sagittaria latifolia). The open water could vary from a series of small pockets (less than 0.5 acres) to a meandering stream serving as a drainage channel for storm flows to enhance sediment trapping and pollutant sequestering and uptake by plants.

2. Multiple Depressions

A second alternative design would be multiple depressions (1-3 acres in size) without distinct interconnecting surface connections. This design would be similar to the "prairie potholes" commonly found in the Mid-western states. These potholes could be crescent-shaped and configured so as to create backwater habitat and assimilate former river channels.

Similar to Alternative 1, the basin bottoms would be created with hummocky microtopography and plantable soils, and would be designed at elevations influenced by the groundwater hydrology. These basins would have very flat side slopes (less than 5 percent), and should be varied slightly in elevation to create a hydrologic variability. We assume that these potholes would be infrequently inundated by large storm events (10+-year storms).

Also similar to Alternative 1 would be the establishment of vegetative zones based on the varying elevations and microtopography. We envision a mixture of upland and seasonally flooded/saturated forested wetlands encompassing the western portion of the site and the potholes. Tree species that would be planted in this area would include those listed for Alternative 1.

Lower in elevation, shrubs will be planted to form a dense, broad perimeter around each pothole, and form the dominant cover of the seasonally flooded wetlands in between the permanently flooded potholes. Facultative (FAC) species would be planted at higher elevations (seasonally flooded/saturated hydrology), while facultative wetland (FACW) and obligate wetland (OBL) species should be planted at lower elevations with a seasonally flooded to semi-permanently flooded/saturated hydrology.

Lowest in elevation with a semi-permanently flooded to permanently flooded hydrology would be an interspersion of emergents, floating aquatics, and open water. Permanent pools depths of 3-4 feet should be created. These areas would contain plant species providing high wildlife food and cover values such as duck potato, arrow arum (Peltandra virginica), and duckweed (Lemna, Wolfia spp.). Other species such as three-way sedge (Dulichium arundinaceum), soft-stem bulrush (Scirpus validus), soft rush (Juncus effusus), and Canada rush (Juncus canadenis) should also be planted or seeded. As proposed, this alternative would be designed as basins lacking distinct inlets or outlets, although storm flows would infrequently flood these basins that would be designed to minimize the potential for erosion during significant flows.

3. Multiple Surface-Connected, Stepped Basins

A variation of Alternative 2 would be to create a series of stepped basins with surface hydrologic connections. The design would include multiple basins (1-3 acres in size) with hummocky topography and meandering, interconnecting flow channels. The basin(s) constructed at the highest elevation(s) in the northern/northwestern portion of the site would be dominated by flooding events of the Blackstone River and runoff from the nearby roadways. This basin would include low permeability soils in the subgrade (with plantable soils creating the final grades) to minimize water loss as groundwater. An earthen or flashboard weir would be constructed to sustain a permanent to semi-permanently flooded pool to a depth of 1-2 feet. Downgradient of the surfacewater-driven pool would be several pools of varying elevations and hydrology but dominated by groundwater. These wetlands would be identical to those previously described for Alternative 2, except these depressions would have interconnecting vegetated channels serving as distinct inlets and outlets carrying storm flows to and from each basin. The basins would eventually discharge at the southeastern portion of the property.

The wetland cover types associated with these basins will be similar to those previously discussed for Alternatives 1 and 2. A greater area of uplands may be associated with this alternative to create distinct flows channels. Mixed upland and wetland forest would provide a well developed wooded buffer along the western portion of the site. Willow and alder wetlands would provide a significant cover of this alternative to assimilate an active floodplain condition. Shrub and emergent vegetation would dominate the basin bottoms. Five- to ten-foot wide channels at various locations throughout the wetland complex will interconnect the wetland basins, as well as different wetland types. These channels would include meanders and possibly check dams or boulders to slow flow velocities. It is expected that persistent emergent vegetation (e.g., switchgrass, fowl-manna grass) would dominate the channels, although shrub vegetation would also likely colonize these channels.

Projected Functions and Values of the Design Alternatives

1. Single Large Basin

A single large basin would logically provide the greatest potential flood storage volume, and therefore, would provide principal flood impact abatement functions. A constricted outlet would help in detaining flow volumes and reducing flow velocities. A single large wetland would also create the greatest potential for *core* wildlife habitat. Large habitats are generally considered as higher value habitat than smaller sites because of edge effects that reduce wildlife habitat quality. This large basin would provide principal wildlife habitat functions, particularly for species sensitive to human disturbances. A single large basin would also provide regional groundwater recharge as a principal function. Also, this alternative may provide the greatest passive recreational opportunities if a viewing platform were constructed in the highest elevations of the site, or canoeing was provided in the open water portions of the wetland. Significant opportunity for public educational and scientific study would also be associated with this alternative, as well as the following two design alternatives.

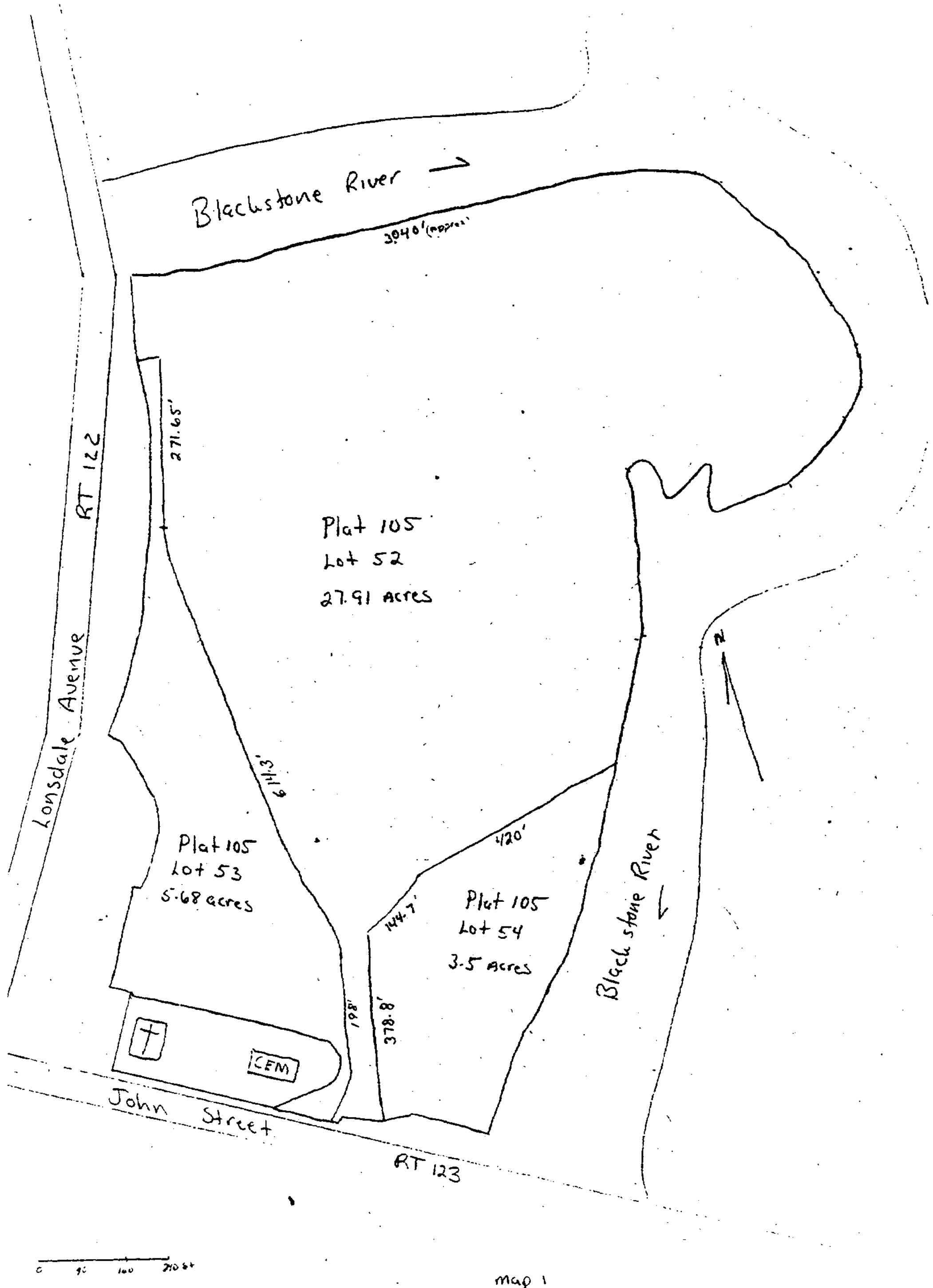
2. Multiple Depressions

Similar to the single large basin, multiple basins would provide groundwater recharge and wildlife habitat as principal functions and opportunity for passive recreation, education and scientific research. Although flood impact abatement would be provided with this design, it would not function to the degree provided by a single large basin. Properly designed, the multiple basins would provide quality feeding, breeding, and cover habitat for waterfowl, other avian species, herpetofauna, and mammals; sediment trapping; nutrient uptake and transformation (denitrification); and pollutant removal (e.g., metals and hydrocarbons). Also, with this design alternative, an interpretive boardwalk could be constructed amongst the basins to enhance educational and recreational opportunities. We caution however, that this alternative could lessen wildlife habitat functioning of these wetlands.

3. Multiple Surface-Connected, Stepped Basins

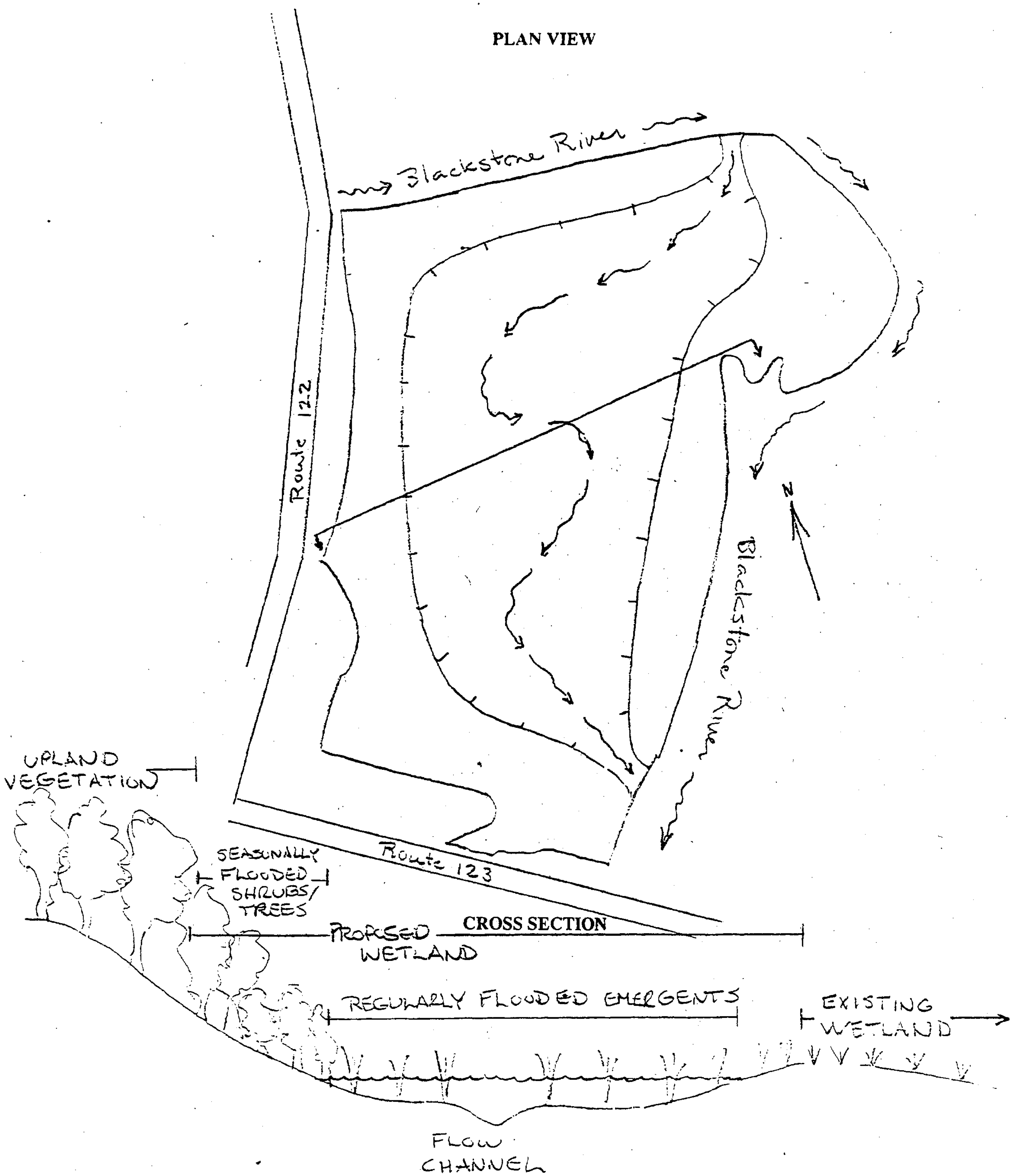
This third alternative design would provide principal functions including flood flow alteration, production export, groundwater recharge, and pollutant removal. High flood impact abatement functions would be provided because of the interconnectedness of these basins and surface connections to the river, although flood storage volume would be less than the single large basin. This design would allow the greatest potential for a more diverse hydrology which, in turn, would likely enhance plant community and animal assemblage diversity. Conversely, less wetland habitat versus upland habitat may be available with this alternative because of the distinct drainage system that would be created. Pollutant removal would be high, as physical trapping, plant uptake, and chemical complexing or transformation would be maximized by the extended time that it would take river flows to pass through these basins. Similarly, production export would be a principal function because of the high edge-to-pool-and-channel ratio that would increase a plant cover along conveyances, transporting organic material from these wetlands to downstream riverine and estuarine ecosystems. Like Alternative 2, a system of boardwalks could be constructed to enhance educational and recreational opportunities. The greatest potential for erosion problems may be associated with this alternative due to the greater number of flow channels. Proper design would help to minimize these potential problems.

Lonsdale Drive-In



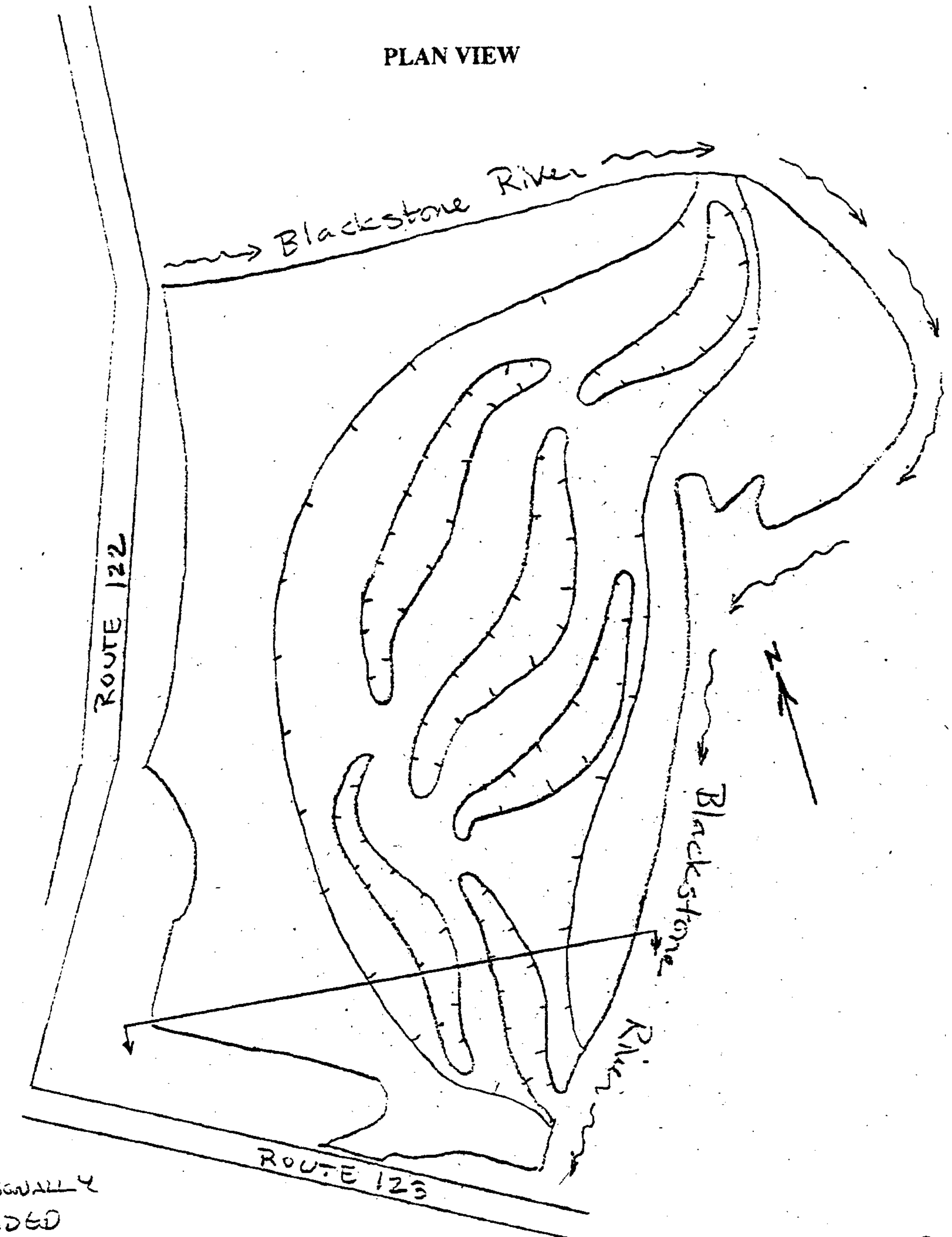
map 1

LONSDALE DRIVE-IN SITE
ALTERNATIVE 1: SINGLE LARGE BASIN

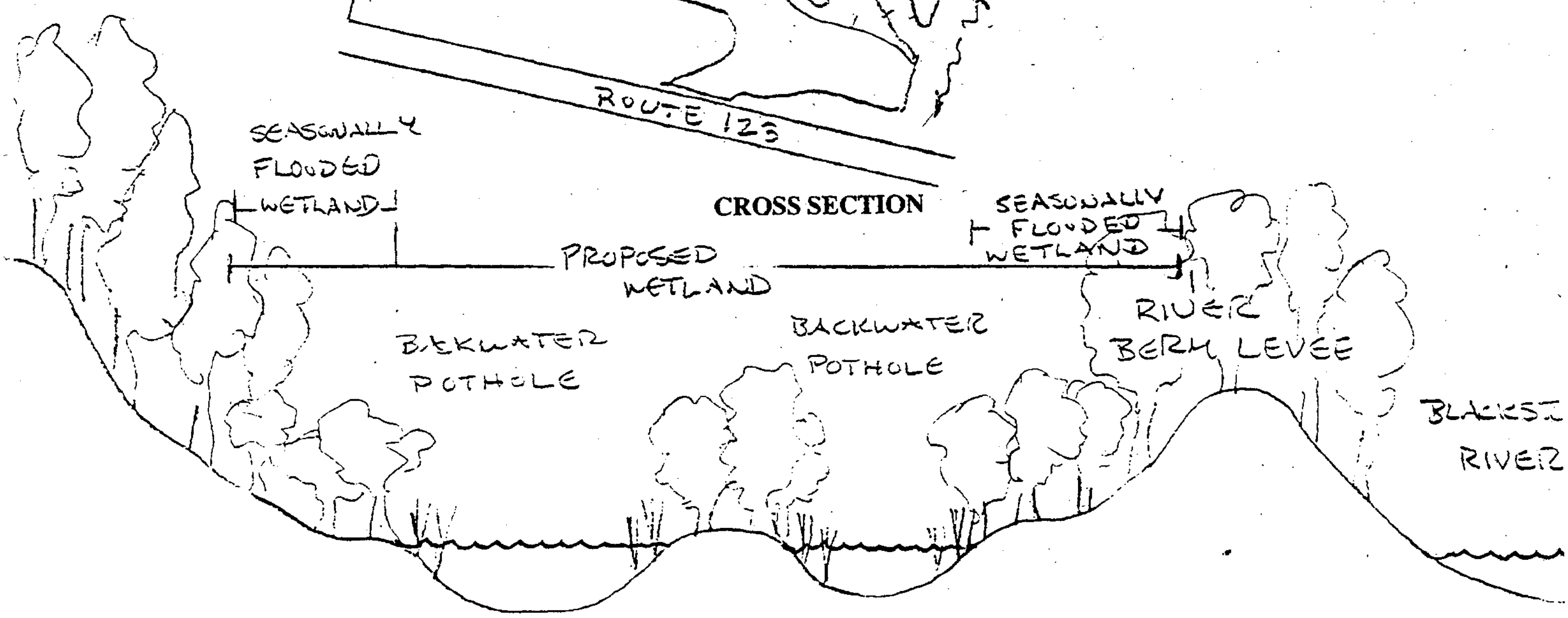


LONSDALE DRIVE-IN SITE
ALTERNATIVE 2: MULTIPLE DEPRESSIONS

PLAN VIEW

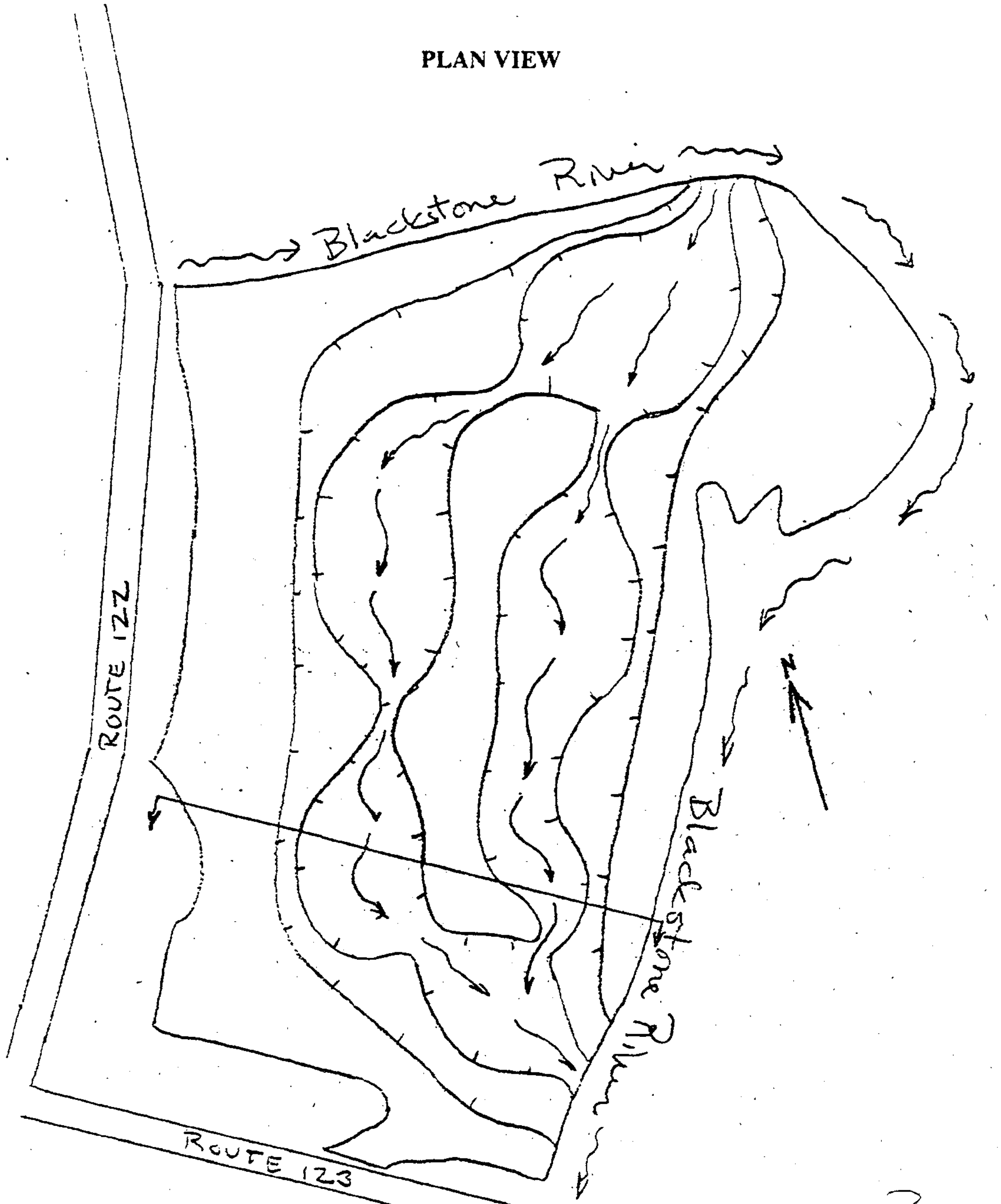


CROSS SECTION



LONSDALE DRIVE-IN SITE
ALTERNATIVE 3: MULTIPLE SURFACE-CONNECTED STEPPED BASINS

PLAN VIEW



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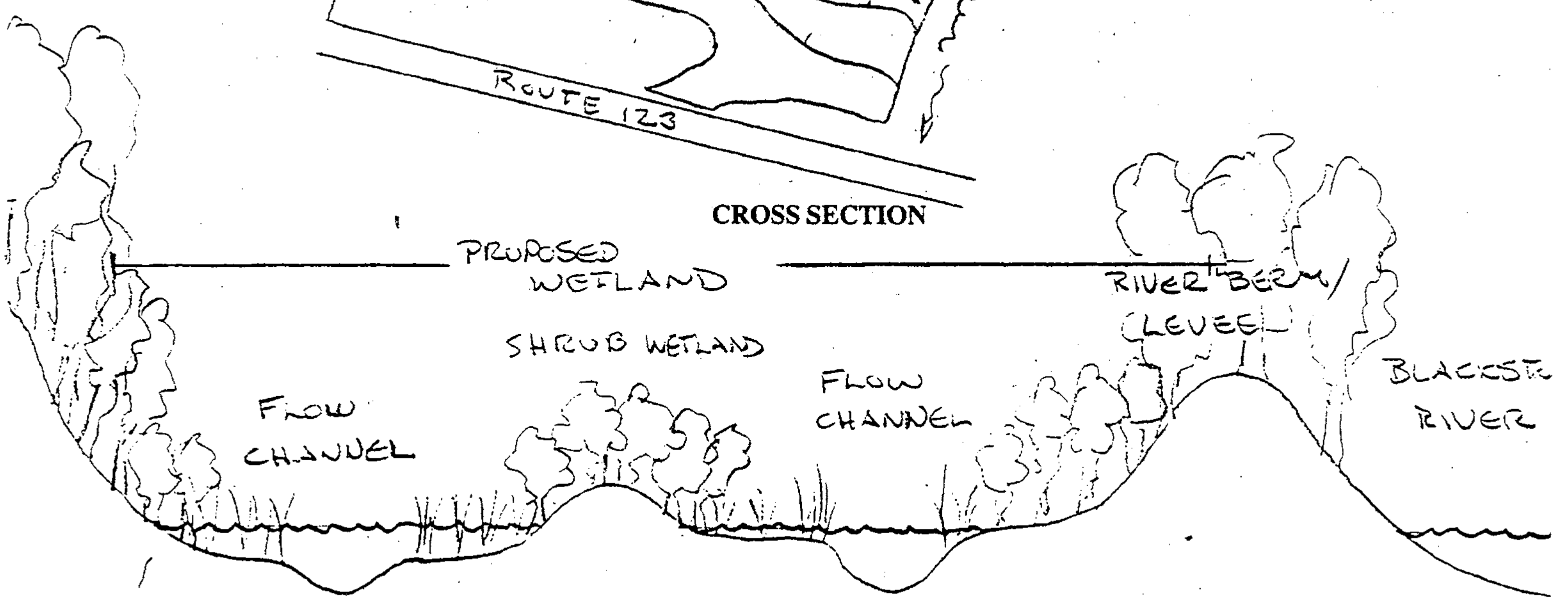

Sierra Club, Rhode Island Chapter
P.O. Box 2464
Providence, RI 02906
(401) 521-4734

One Earth, One Chance

Dec. 17, 1996

Governor Lincoln Almond
222 State House
Providence, RI 02903

Dear Governor Lincoln Almond:

The Rhode Island Chapter of the Sierra Club has long been concerned with wetlands protection in our state including the restoration of previously impacted habitats. In recent years, we have been diligently working to rally support for conservation of ecologically valuable wetlands within the Blackstone River watershed.

We are requesting your help in order to take full advantage of an immediate opportunity in the Blackstone Valley that would protect and restore approximately 47 acres of wetland and upland habitat at the defunct Lonsdale Drive-In in Lincoln. It is our position that this site has a high potential for restoration of wetlands contributing significant ecological functions, since the remaining portion of the adjacent Lonsdale Marsh is a state-designated critical habitat for both resident and migratory birds and other wildlife. A secondary benefit could be a substantial increase in floodwater storage and storm flow reduction along this portion of the Blackstone.

Sierra Club has urged the Rhode Island Department of Environmental Management (RIDEM) to purchase the property. RIDEM's recently published Strategic Assessment includes both a mission and a goal to restore important water resources in the state. In particular, RIDEM proposes to target urban waterbodies for remedial actions, and plans to identify and acquire priority land parcels that meet criteria established in existing state plans to enhance the state's biological diversity. We feel that the Lonsdale parcel clearly meets all these objectives; the site is located in a highly urbanized area, and the Lonsdale Marsh has been identified by RIDEM as the most important wetland system in northern Rhode Island. Restoring and safeguarding this parcel through public or land trust ownership would be a significant benefit to Rhode Islanders and contribute to the overall success of RIDEM's strategic plan.

We were thrilled to learn that RIDEM has begun negotiations with the property owner, and we support them in their efforts. However, because of limited state-based funding, RIDEM has been considering allowing the owner to develop the uplands and a portion of the wetlands in exchange for floodplain compensation. While some wetlands could be restored this way, it would result in a lost opportunity for larger habitat restoration that could be easily achieved by using alternative sources of funding.

Our members would prefer that the entire property be purchased for conservation purposes. We feel that it makes sense for the state to complete the purchase while land costs are relatively low. The on-site forested and non-forested uplands would serve as a valuable buffer between the restored wetlands and nearby roads and development. A varied habitat would also enhance anticipated wildlife, passive recreation and aesthetic values. A portion of the disturbed uplands might even be considered as a location for a viewing platform or other features which could provide opportunities for public education and wildlife observation, meeting yet another goal of RIDEM's Strategic Assessment.

Right now we urgently need to demonstrate to RIDEM that utilizing federal sources for this type of restoration work is practical. In recent conversations with the U.S. Army Corps of Engineers about the Lonsdale Drive-In site, they indicated that funds are available for restoration in a 75% cost-share partnership; in other words, unless the restoration is three times the cost of the property, RIDEM would not need to invest anything more than the purchase of the property. At the U.S. Fish & Wildlife habitat restoration meeting yesterday, the Army Corps agreed to meet with RIDEM to offer assurances of the availability of this money. The contact person there is Mike Penko (617/647-8139).

We would greatly appreciate any support you and your staff could offer to protect the entire parcel and to encourage RIDEM and the Corps (and/or other potential funding agencies) to work together.

Please let us know if we can facilitate this process and do not hesitate to contact Ms. Karina Lutz (401-521-4734) or Helen Tjader (401-245-6209), should you have any questions or comments on this project.

We wish you and your family a very enjoyable and safe holiday season.

Sincerely,

Helen Tjader
Chair, Rhode Island Chapter

Adam Werbach
President, Sierra Club

cc: Senator John Chafee
Representative Patrick Kennedy
Representative Robert Weygand
Governor Lincoln Almond
Commissioner Timothy Keeney
Ed Szymanski
Lisa Pointek
Claude Cote

JACK REED
RHODE ISLAND

COMMITTEES
BANKING
LABOR AND HUMAN RESOURCES
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United States Senate

WASHINGTON, DC 20510-3903

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(401) 528-5200
TDD RELAY RHODE ISLAND
1-(800) 745-5555

February 20, 1997

Col. Robert W. Burkhardt
Executive Director
Directorate of Civil Works
U.S. Army Corps of Engineers
20 Massachusetts Avenue, N.W.
Washington, D.C 20314

Dear Col. Burkhardt:

I write on behalf of the Rhode Island Chapter of the Sierra Club.

Ms. Helen Tjader forwarded my office the enclosed correspondence regarding proposed wetland restoration. According to Ms. Tjader, the Rhode Island Sierra Club has urged the Rhode Island Department of Environmental Management to purchase 47 acres of wetland and upland habitat at the defunct Lonsdale Drive-in site in Lincoln, Rhode Island. In addition, Ms. Tjader states that involvement by the Army Corps of Engineers could be useful in completing the project.

I would appreciate any information you can provide regarding the restoration of the Lonsdale Drive-in site. Please do not hesitate to contact me if you have any questions regarding this proposal.

Thank you for your attention to this matter. I look forward to your response.

Sincerely,

Jack Reed
United States Senator

JFR:ep

APPENDIX C - LETTERS OF INTENT

The Commonwealth of Massachusetts
Executive Office of Environmental Affairs
100 Cambridge Street, Boston, MA 02202

ARGEO PAUL CELLUCCI
GOVERNOR
TRUDY COXE
SECRETARY

Tel: (617) 727-9800
Fax: (617) 727-2754
http://www.magnet.state.ma.us/envir

August 22, 1997

John R. Kennelly III, Chief
Long Range Planning Branch
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254

Dear Mr. Kennelly,

This letter is in response to the draft report Blackstone River Watershed Reconnaissance Investigation and the draft Project Study Plan included in your July 30, 1997 letter to George Crombie. As you are aware, we still in the process of commenting on the draft report and the draft Project Study Plan.

During our meeting on August 12th we had the opportunity to discuss Blackstone River Project and the cost-share responsibilities of local sponsors associated with the feasibility and construction phases of this project. I understand these responsibilities and am willing to enter into negotiations to define the scope of the feasibility study and determine the cost-share responsibilities of the Commonwealth of Massachusetts for the next phase of this project. I look forward to working with you, and with representatives from Rhode Island and other potential local sponsors, to refine the current draft and develop a mutually agreeable Project Study Plan.

If you have any questions, please feel free to call.

Sincerely,

Mark P. Smith
Director of Water Policy and Planning

cc: George Crombie

RHODE ISLAND
DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

235 Promenade Street, Providence, RI 02908-5767 TDD 401-831-5508

August 22, 1997

Mr. Richard D. Reardon, P.E.
Chief, Engineering/Planning Division
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Dear Mr. Reardon:

Representatives of the Department of Environmental Management have met with your staff and have reviewed the draft Project Study Plan for the proposed Blackstone River Watershed Feasibility Study. Please be advised that we understand the feasibility and construction cost-sharing responsibilities and we are willing to enter into negotiations for the feasibility phase. We look forward to continuing project plan discussions.

Sincerely,

Frederick J. Vincent

Frederick J. Vincent
Acting Director

FJV/jsb
cc: David V.D. Borden
John O'Brien

VIA FAX

APPENDIX D - FEASIBILITY COST-SHARING AGREEMENT WITH DRAFT PROJECT STUDY PLAN

BLACKSTONE RIVER WATERSHED INVESTIGATION
DRAFT PROJECT STUDY PLAN

I. PURPOSE OF PROJECT STUDY PLAN

This document outlines the draft Project Study Plan (PSP) in accordance with ER 5-7-1 and ER 1105-2-100 for the conduct of the Feasibility Study for the Blackstone River watershed. This draft PSP is provided by the New England District for discussion/negotiation purposes with the potential study sponsors, the Commonwealth of Massachusetts and the State of Rhode Island and Providence Plantations.

The draft PSP details the scope, schedule, and budget of Feasibility Study tasks as well as the division of responsibilities for accomplishment by the New England District, the sponsors, and the respective consultants and contractors. Included in the draft PSP is a detailed work description, cost-summary table, and preliminary schedule outlining the initiation and completion of tasks by the New England District and the sponsors.

The draft PSP will be the basis for negotiations between the New England District and the non-Federal sponsors. Once the terms have been agreed to, the draft PSP must be approved by the North Atlantic Division and certified by Headquarters, U.S. Army Corps of Engineers (HQUSACE).

II. SCOPE OF WORK

The Blackstone River Watershed Feasibility Study includes all studies required in preparation of a favorable report to be processed to the U.S. Congress for authorization. This plan includes work descriptions, costs, and preliminary schedules for the following products:

- Work Plan for Feasibility Report
- Feasibility Report
- Draft and Final Environmental Impact Statement (EIS) or Environmental Assessment (EA)
- Preliminary Project Cooperation Agreement (PCA) and Financing Plan
- Draft Project Management Plan (PMP) for Preconstruction Engineering and Design (PED), including preparation of Plans and Specifications for the initial construction contract
- Other Supporting Plans

III. RECONNAISSANCE STUDY OVERVIEW

A. Purpose of Reconnaissance Study

The New England District conducted a reconnaissance study to assess the ecological problems and needs of the Blackstone River watershed. Projects were examined with an emphasis on environmental restoration. The Blackstone River Watershed Reconnaissance Investigation was performed under authority of a resolution of the Committee on Public Works of the United States Senate adopted September 12, 1969. This resolution gives the Army Corps of Engineers the authority to investigate solutions for "flood control, navigation, and related purposes in Southeastern New England ..."

B. Scope of the Reconnaissance Study

The Blackstone River basin has a drainage area of 475 square miles, with 335 square miles in south central Massachusetts and 140 square miles in northern Rhode Island. The Blackstone River begins in the southern part of Worcester, Massachusetts at the confluence of the Middle River and Mill Brook and flows southeasterly for 46 miles to the Main Street Dam in Pawtucket, Rhode Island. Below the Main Street Dam is the tidal Seekonk River, which in turn flows south to the Providence River, a northern arm of Narragansett Bay.

The reconnaissance study was performed in order to accomplish four tasks: (1) to identify problems, opportunities, and potential solutions, (2) to determine whether more detailed investigations were warranted as part of a Feasibility Study, based on a preliminary appraisal of costs, benefits, environmental impacts, and consistency with Corps policies, (3) to estimate the time and cost of the tasks required for a Feasibility Study, and (4) to assess the interest and capability of a non-Federal sponsor(s) to participate in a cost-shared Feasibility Study.

Existing or readily available data, general site inspections, interviews, and map analysis were used as the basis for conducting preliminary analyses and evaluations, supplemented by additional sediment toxicity data collected for this study at one of the mainstem river prototype project sites. Where information was not available, suitable assumptions were made based on standard environmental and engineering practice. Both monetary and non-monetary benefits were estimated. The information that was gathered was used to facilitate comparisons among alternative projects and plans in the decision-making process. Detailed comparisons of plans, design of project features, assessment of environmental impacts, preparation of plans and specifications, and construction will be accomplished in project phases subsequent to the reconnaissance study.

C. Tasks and Products of Reconnaissance Study

Tasks for this reconnaissance study were organized as follows:

Task 1 - Identify Baseline Conditions
Task 2 - Identify Problems, Needs, and Opportunities
Task 3 - Develop Potential Solutions
Task 4 - Formulate Site-Specific Solutions
Task 5 - Develop Water Resources Plan
Task 6 - Report Preparation
Task 7 - Public Involvement and Coordination

D. Findings of Reconnaissance Study

The reconnaissance investigation examined the ecosystem of the Blackstone River watershed and found significant ecological problems including: lost or degraded wetlands, instream, pond and riparian habitat; loss of a historic anadromous fishery; degraded waterfowl habitat; degraded resident fisheries; contaminated sediments; and poor water quality. The study identifies a broad array of potential solutions to be implemented by the Corps and others to address the Blackstone River basin's ecological problems, and presents preliminary designs and cost estimates for example projects believed most appropriate for the watershed. The proposed projects, although not representing anywhere near the full extent of work required to restore the ecological health of the watershed, would significantly improve the watershed's ecological health, particularly that of the mainstem river. The construction of similar projects throughout the study area would be required to achieve a dramatic improvement in the watershed's ecological health.

The reconnaissance investigation identified two major issues which need to be addressed prior to proceeding with the larger restoration projects. The first issue concerns the risk posed by contaminated sediments. A thorough assessment of the ecological and human health problems caused by contaminated sediments is a critical first step in developing a restoration plan for the watershed. Since limited sediment coring performed by others indicates that contamination worsens with depth, risks may also increase with depth, perhaps impacting the feasibility and/or cost of dredging opportunities to restore lost habitat. The second issue is that of resuspending sediments. Sediment loads should be identified under a broad range of flow conditions to identify restoration opportunities appropriate for each area. It is presently unclear if cleaner sediments from new sources are capping more contaminated older sediments.

Many of the proposed restoration actions clearly are within the realm of the Corps of Engineers environmental restoration mission. Specific and generic examples of these actions include:

- ☐ the "Lonsdale Drive-In" project in Lincoln, Rhode Island, to address wetland habitat deficiencies;

- the conversion of abandoned gravel pits into shallow emergent/open water habitat areas to restore habitat lost at other locations elsewhere in the watershed;

- the Fisherville Pond project in Grafton, Massachusetts to restore both wetlands and open water habitat behind a dam by providing additional waterfowl and open water/emergent wetland habitat;

- the stabilization of unsafe dams whose failure would result in the loss of the habitat behind the dam(s) and the release of contaminated sediments causing habitat loss both downstream of the dam(s) and in Narragansett Bay;

- the evaluation of under-utilized dams throughout the watershed to assess their possible removal to restore river/stream habitat;

- the restoration of anadromous fish to the watershed. Through the construction of fish passage facilities at several of the lower dams and the development of a phased plan for the restoration of the fish to remaining portions of the watershed.

The Reconnaissance Study identifies a Federal (Corps of Engineers) interest in performing environmental restoration in the Blackstone River watershed. The reconnaissance report recommends that a Feasibility Study be performed to identify, assess, and prioritize all of the sites in the Blackstone River basin where such projects would be appropriate. The Feasibility Study would also identify those actions required by other Federal, state, and local agencies to optimize the environmental benefits of the Corps projects. The total cost of the projects proposed in the Reconnaissance Study is $18,400,000 (includes Alternative 1 of both the Fisherville and Lonsdale Drive-In projects), based upon the assumption of relatively benign sediments in the basin. It is likely that the Feasibility Study will identify several more such projects throughout the watershed. Implementation of the recommendations included in the ecological restoration plan would alleviate the significant water resources-related ecological problems in the Blackstone River watershed. The comprehensive plan would be implemented with full cooperation of local, state, and Federal agencies.

IV. FEASIBILITY STUDY OVERVIEW

A. Purpose of the Feasibility Study

Water resources studies undertaken by the Corps of Engineers are conducted in two phases - a reconnaissance phase and a feasibility phase. The two phase study procedure is designed to encourage non-Federal participation throughout the study process and to increase the certainty that planned projects will be implemented.

The purposes of the feasibility phase are:

- To conduct detailed engineering, economic, environmental, and cultural investigations to support plan formulation and evaluation;
- To identify the National Economic Development (NED) Plan or Locally Preferred Plan as applicable;
- To identify the National Environmental Restoration (NER) Plan;
- To identify environmental restoration projects eligible for Corps participation, produce high priority environmental outputs and are incrementally justified;
- To comply with National Environmental Policy Act (NEPA) requirements by preparing an Environmental Impact Statement (EIS) or Environmental Assessment (EA);
- To estimate costs and benefits to a level of detail suitable for project justification, if applicable;
- To determine the appropriate construction cost-sharing arrangements and obtain non-Federal support, as necessary;
- To prepare appropriate documentation for Federal project authorization; and
- To recommend favorable projects for authorization and construction, if appropriate.

B. Scope of Feasibility Study

The Feasibility Study area will be the same as for the reconnaissance study. As part of the Feasibility Study, information will be obtained which will include data collection and modeling programs, detailed site-specific investigations, detailed mapping, and utilization of a Geographic Information System (GIS). Estimations and assumptions made during the reconnaissance study will be reviewed for accuracy once acceptable data is available. Detailed designs and cost estimates for construction will be prepared.

The anticipated product would be a Feasibility Report for the Blackstone River watershed, accompanied by an environmental document to comply with NEPA. The Feasibility Report would provide all the necessary documentation to permit project authorization by the U.S. Congress for construction of a Federal project(s), if justified. The Feasibility Report would build upon the information contained in this reconnaissance report and would include:

- A detailed examination of the Blackstone River watershed.
- A detailed examination of the ecological and human health risks posed by contaminated sediments.
- A detailed examination of environmental restoration opportunities, including the restoration and/or creation of wetlands, riparian, and riverine and pond habitat.
- An examination of the role of the Corps of Engineers in implementing fish passage facilities at hydropower dams licensed by the Federal Energy Regulatory Commission, and in stabilizing non-Federal dams.
- A detailed examination of recreation opportunities.
- Detailed investigation of site characteristics, including topographic and bathymetric mapping and subsurface exploration.
- Hydraulic modeling of the watersheds.
- Data collection and sampling to be used for modeling effort.
- Formulation of practical alternatives, considering the nature of the problem, site characteristics, and area resources.
- A thorough consideration of the multiple purpose potential of environmental restoration projects.
- Assessment of the environmental effects of the possible solutions, and preparation of an Environmental Impact Statement or Environmental Assessment as applicable.
- Investigation of possible impacts to cultural resources with results and determination of effects coordinated in accordance with Section 106 (Public Law 89-665, as amended) responsibilities.
- Coordination with the U.S. Fish & Wildlife Service (USFWS) including receipt of a Fish and Wildlife Coordination Act Report.
- Preparation of typical design drawings and quantity estimates.
- Estimation of project costs and benefits.
- Evaluation and ranking of feasible solutions.

- Identification of the NED Plan or Locally Preferred Plan as applicable.
- Identification of the NER Plan.
- Preparation of a preliminary hazardous, toxic, and radioactive waste assessment or chemical analyses of dredged material in accordance with the Clean Water Act.
- Compliance with other environmental laws and regulations as appropriate.
- A public involvement program to ensure that the public's concerns are addressed and that the public is kept apprised during the conduct of the Feasibility Study.
- Analysis of project implementation arrangements, including construction cost-sharing requirements and an ability-to-pay analysis of the non-Federal sponsor's project financing plan.
- Preparation of a Project Management Plan (PMP) which describes the tasks required during the Preconstruction Engineering and Design (PED) phase and associated costs.
- Recommendation for authorization and construction, if a project(s) is economically justified and supported by non-Federal sponsors.

C. <u>Feasibility Cost Sharing Agreement</u>

Administration policy permits the expenditure of Federal funds for all costs associated with the reconnaissance phase. Section 105(a)(1) of the Water Resources Development Act of 1986, however, requires that the cost of a subsequent feasibility phase be shared equally (50/50 split) between the Federal government and a non-Federal sponsor(s).

Up to one-half of the non-Federal contribution, or one-quarter of the total cost of the feasibility phase, may be in the form of in-kind services. In-kind services are those tasks performed and paid for by the non-Federal sponsor which are in direct support of the Feasibility Study effort. While all in-kind services should be in support of the particular study, it is permissible for non-Federal sponsors to reorient existing programs and on-going work to complement the Corps Feasibility Study.

To proceed beyond the reconnaissance phase, the Federal government and the non-Federal sponsor must agree that the proposed project is in the Federal and non-Federal interest and then negotiate a Feasibility Cost-Sharing Agreement (FCSA) that commits both parties to equally sharing the feasibility phase cost. The FCSA is intended to promote a partnership for conduct of the feasibility phase. It sets forth the management structure, obligations of the signatories, methods of payment, resolution of disputes, methods for termination or suspension of the Feasibility Study, and other general contractual matters.

Federal funds to initiate the feasibility phase may be allocated only after a negotiated FCSA has been prepared and all documents have been certified by Corps higher authority. The feasibility phase can then begin after execution of the FCSA and receipt of both Federal and non-Federal funds.

D. Draft Project Study Plan

As part of the FCSA, a draft Project Study Plan (PSP) is prepared and negotiated. The draft PSP (this document) describes the specific Federal and non-Federal efforts which will be required to conduct a particular feasibility phase. The draft PSP is appended to the FCSA, and lays out the work tasks, costs, and schedules for the entire feasibility phase. It also furnishes a basis for identifying the in-kind services to be provided by the non-Federal sponsor and for negotiating the value of these services. Significant changes to the draft PSP during the Feasibility Study will require a modification of the FCSA.

E. Identification of Potential Non-Federal Sponsors

The potential non-Federal sponsors are the Commonwealth of Massachusetts and the State of Rhode Island and Providence Plantations. Representatives of various departments and agencies of the two potential sponsors have been involved in key aspects of the reconnaissance study including selection of prototype projects. Preliminary support has been provided verbally by the points of contact designated by the potential sponsors, albeit to differing extents.

V. DESCRIPTION OF PRODUCTS

This draft Project Study Plan covers the development of four products prior to the initiation of Preconstruction Engineering and Design including:

A. Feasibility Report

This product includes all activities leading to the approval of the final Feasibility Report/Environmental Assessment by the Headquarters, US Army Corps of Engineers (HQUSACE). It entails all problem identification and formulation activities required to identify and recommend plans of improvement. It also includes NEPA, Section 106, and other environmental compliance documentation; coordination of the study and results with all interested parties; review by the North Atlantic Division and HQUSACE, and ultimately, transmittal to Congress. The Feasibility Study, culminating in the Notice of the Division Engineer, is scheduled for completion in FY2000.

B. Environmental Impact Statement (EIS) or Environmental Assessment (EA)

This product includes all activities leading to the assessment of environmental impacts related to the various projects being investigated. This includes scoping and preparation of the environmental document, public coordination and review, and notification of findings.

C. Preliminary PCA and Financing Plan

As the details of the recommended plans are finalized, coordination will be undertaken with the local sponsors to review the model language for Project Cooperation Agreements (PCA) for the various projects. Letters of intent will be developed which acknowledges the requirements of local cooperation and expresses good faith intent to provide those items for the recommended project. Additionally, preliminary financing plans will be developed by the sponsors to detail plans for financing costs. Assessment of these plans will then be completed by the District.

D. Draft Project Management Plan (PMP)

As part of the Feasibility efforts, draft PMPs will be prepared based on the recommended projects and a baseline cost estimate will be developed. The draft PMPs will address the schedule of PED activities. This includes design memorandums and preparation of plans and specifications for the initial construction contracts. The draft PMPs will address the development of additional products and more detailed plans for successful management and completion of the projects. These documents will form the basis for the PMPs to be finalized for project construction. The draft PMPs will be submitted with the draft report.

E. Other Supporting Plans

Other supporting plans will be developed as needed as the study progresses to address specific items such as local cooperation, real estate acquisition, quality control, value engineering, environmental and cultural matters, safety and security, and operation and maintenance.

Reporting requirements in ER 5-7-1, entitled Project Management, Life Cycle Project Management System, will be adhered to.

VI. ORGANIZATIONAL BREAKDOWN

The purpose of this section is to define the study organization and the roles and authorities in accomplishing the study.

A. Executive Committee

As indicated in the FCSA, the overall study management is the responsibility of the Executive Committee which is comprised of the New England District Engineer, the Chief of

Programs and Project Management Division, the Chief of Engineering and Planning Division, the Secretary of the Commonwealth of Massachusetts' Executive Office of Environmental Affairs, the Director of the State of Rhode Island and Providence Plantations' Department of Environmental Management, or their representatives. The Executive Committee will meet periodically throughout the study to review study progress, finances, and findings as developed and reported by the study team. The Chief of Planning Branch, New England District, will act as alternate for the Chief of Engineering and Planning Division while also serving as liaison to the study team.

B. Study Team

The study team is responsible for accomplishment of the study in accordance with the FCSA, draft PSP, and appropriate Federal and State guidance and regulations. The study team will regularly meet to coordinate on study progress, interim findings, financial status, and all matters related to conduct and completion of the study.

The study team is composed of representatives from the New England District, Engineering and Planning Division (Planning Branch, Geotechnical and Water Management Branch, Design Branch, and Evaluation Branch), Construction and Operations Division, Real Estate Division, and Programs and Project Management Division. In addition, representatives of the sponsor(s) are also included as part of the study team.

C. Programs and Project Management Division

The Project Manager (PM) is responsible for reporting to the District's Project Review Board and for preparation of required Life Cycle Project Management (LCPM) reports. In addition, PM responsibilities include the monitoring of project schedules and finances, processing of schedule and cost change requests, management of contingencies, review of budget documents, coordination of the FCSA and Project Cooperation Agreements (PCAs), and identification of problems and issues.

The study team has the responsibility of study formulation, technical project management, and development of the Feasibility Report. A technical manager (TM) will be assigned as the representative of each of the technical divisions. The development of a timely, quality product within the established task budget is the responsibility of the TM for each task and ultimately, the PM. In addition, the individual elements are responsible for scope of work preparation, contract negotiation, and performance of any work to be completed by consultants or other Federal agencies.

D. Planning Branch

Planning Branch is responsible for study management, including the preparation of study schedules, leading plan formulation, monitoring the progress of technical work, developing and preparing the Feasibility Report, development of economic data and demographic information, evaluation of economic impacts, development of environmental and cultural data, development of incremental analyses for justification of environmental projects, assessing environmental impacts, preparing mitigation plans, and accomplishing environmental compliance.

E. Geotechnical and Water Management Branch

Review and/or completion of design studies of foundations, groundwater, dredged material placement areas, and other geotechnical matters including subsurface exploration and sediment testing are accomplished by the Geotechnical Engineering Section. The Water Management Section is responsible for studies to determine hydrology.

F. Design Branch

Input from Civil Engineering Section and General Engineering Section will be coordinated by the Design Branch Chief. Civil Engineering Section prepares the plans for proposed projects and determines the quantities of materials used, excavated, dredged, etc. Involvement by the General Engineering Section occurs when the subject material is non-earthen, i.e. concrete or other. Development of cost estimates for initial construction and maintenance of alternative plans and the selected plans is the responsibility of the Cost Engineering Office.

G. Construction and Operations Division

The Survey Section, Technical Support Branch of the Construction and Operations Division, will assist in projects requiring surveying and mapping. The Construction Services Branch is responsible for reviewing and providing input into the designs to ensure that the potential projects are buildable.

H. Real Estate Division

The Real Estate Division is responsible for the real estate plan and development of PCAs. The real estate plan will include a baseline cost estimate for real estate, development of a detailed schedule of acquisition milestones, and a general description of the area and total acreage to be acquired, with fee and easement breakdown. The Real Estate Division TM will also be responsible for securing rights-of-entry as necessary for technical data collection.

VII. PRELIMINARY SCHEDULE

The schedule for a typical feasibility phase covers 24 to 36 months, including a public review period. Development of a firm schedule for the Blackstone River watershed Feasibility Study would be part of the negotiations leading to a final FCSA.

The Feasibility Study initiation date is tentatively scheduled for January 1998. The Feasibility phase can begin only after approval and certification of the reconnaissance report, negotiation and signature of the FCSA, and receipt of both Federal and non-Federal funds.

This draft PSP reflects New England District capability. The preliminary milestone schedule assumes that funding for the study is provided for FY98 and that subsequent years are funded as required to effectively accomplish the study.

VIII. WORK TASKS

Major work tasks for a Feasibility phase are identified in terms of the general activities which are included in the Corps of Engineers standard Study Cost Estimate for General Investigations. These tasks, in turn, were further divided into subtasks which were specifically applicable to the Blackstone River watershed study. The subtasks cover further refinements of the information already gathered; development of new information where data was not previously available; detailed assessments and evaluations of proposed plans; management and coordination activities; and report preparation and processing. The Feasibility Study tasks include the following:

Task 1 - Public Involvement. The Corps will maintain coordination with Federal, state and local agencies and interest groups throughout the conduct of the Feasibility Study. At least two general public meetings and four state agency workshops (combined MA and RI) will be held during the Feasibility Study. Meetings will also be held with local officials (not the local sponsors), as needed. Public notices will be issued, media and public inquiries will be responded to, and coordination and briefing of various committees and organizations will be performed.

Task 2 - Dams/Ponds Inventory and Assessment. The Feasibility study will determine the size, condition/safety, capacity, surface area, ownership, purpose, and National Register status/eligibility of each dam in the watershed. The study will also determine the fish and wildlife habitat value, and recreational values/opportunities at each of the impoundments. The analysis will use existing information from Offices of Dam Safety in either state, FERC information, SHPOs, and newly generated information through dam owner inquiries (if possible), or field estimates. The study will determine dam break scenarios and the impacts to both the pond behind the dam and to downstream resources were dam failure to occur. Estimated volumes and rates of sediment washout will also be determined. The study will assign a rating system for dams representing their likelihood to fail. The fish and wildlife habitat value of each impoundment is to be assessed using a rapid assessment protocol developed in conjunction with the USFWS and state agencies. A determination will be made on individual dams on whether they should be retained or removed in light of ecological, recreational, industrial, and historic needs/values. This analysis will also factor in the costs of dam rehabilitation versus dam removal, and the safety of the dams. Based on the information gathered, a prioritized list will be made of the dams in need of repair.

Task 3 - Inventory of Habitat Restoration Opportunities. The study will develop a comprehensive basin-wide inventory of wetland, riparian, pond, streambank, and in-stream habitat restoration opportunities. Sites will be identified through analysis of color infrared aerial photos, other available data (USFWS National Wetlands Inventory maps, soils maps), results of the dam/pond inventory (Task 2), coordination with state and Federal resource agencies, and field investigations. Site location will be determined by GPS and mapped on state GIS maps. Priority sites for possible restoration by the Corps and others will be identified, and detailed plans/impact assessment/cost estimates will be developed for those projects selected for Corps implementation (Task 11).

Task 4 - Sediments Assessment. The Feasibility Study will include a baseline ecological and human health risk assessment at several of the most heavily contaminated impoundments (large and small) to determine if sediment remediation is required. Based on the results of the Fisherville Pond preliminary baseline assessment, studies will likely focus on risk to benthic invertebrates and fish community. The studies will include additional whole sediment and pore water toxicity testing, whole sediment chemical and physical (grain size) analysis, AVS/SEM testing, benthic invertebrate community studies, and fisheries studies. If sediment remediation is deemed advisable, additional studies might be needed to determine toxicants and establish remediation goals. At each impoundment, studies would be conducted to determine sediment stratigraphy and sediment volume. Whole sediment chemical testing would be conducted to map sediment contamination, including the location of any "hot spots". Toxicity testing of underlying sediment which would be exposed by dredging would also be assessed. TCLP, petroleum hydrocarbon, PAH, and PCB analyses would be conducted to help assess sediment disposal options.

Task 5 - Perform Hydrological and Hydraulic Studies. An analysis of streamflows will be conducted at all proposed restoration project locations. The analysis will assess streamflow under a wide array of conditions, including flood events, summertime low flows, fish migration seasons, and 7Q10 flows. Streamflows will be determined for various purposes, including the sizing of outlets, spillways, canal diversions, to obtain water velocities needed for sediment resuspension studies and bioengineering of streambanks, to determine fish passage success, to determine water quality impacts, to determine depths and their frequency suitable for fish, waterfowl, and recreational purposes, etc. It may be necessary to determine flow variations downstream of each of the mainstem river's hydropower facilities in order to determine causes of the fluctuations to assist followup activities to eliminate these fluctuations. The study will also determine minimum instream flows needed for various purposes including ecological (in coordination with project biologists) and recreational flows. Cross-section and flow information will be used to determine water velocities and depths, develop ratings curves, size canal headgates, outlets, spillways, etc. Water velocities are critical for bioengineering projects, while water depths are critical for waterfowl and other habitat purposes, for sediment capture, and for recreational purposes.

Task 6 - Perform Topographic and Hydrographic Surveys. Cross-sections will be surveyed for numerous purposes, including to obtain water depths at project locations, to obtain dam and canal diversion elevations, etc. Detailed contour mapping may need to be developed, particularly in areas being considered for sediment remediation. A combination of hydrographic and land surveys is likely to be required.

Task 7 - Perform Water Quality (WQ) Modeling. WQ modeling will be performed to determine the impacts of proposed projects on WQ, particularly, dissolved oxygen. Projects proposed may include alterations of water surface elevation, changes in detention time, diversion of all or portion of the streamflow around specific dams or contamination "hot spots", or the removal of dams. These projects are likely to impact nutrient balances, sediment resuspension, sediment oxygen demand, etc. The suitability of the existing QUAL2E computer model for Feasibility Study purposes will be assessed. If unsatisfactory, a suitable model shall be set up and calibrated. Water quality data gaps shall be filled, and intangible water quality problems assessed (odor, appearance, etc.).

Task 8 - Determine Sediment Loads. Sediment loading should be determined for major restoration sites under a broad array of flows and weather conditions. The role of water depths in specific ponds on resuspension should be assessed.

Task 9 - Assess Options with Respect to Contaminated Sediments. For impoundments requiring sediment remediation, the Feasibility Study will provide engineering, cost, and environmental assessment of potential sediment remediation technologies including dredging, bioremediation, sediment washing, and capping.

Task 10 - Anadromous Fish Passage at Dams. The development of a Strategic Anadromous Fish Restoration Plan (SAFRP) will require research, coordination, field work, surveys and evaluations. Coordination with the Federal Energy Regulatory Commission and relevant interested parties to determine what is an acceptable SAFRP will occur. The process of reopening the license and/or exemption conditions that "fish passage facilities and other appropriate project modifications shall be provided when the RIDFW implements a plan for restoring anadromous fish to the Blackstone River" will be determined and follow-through actions taken. Final fish passage design at the lower four dams will occur as well as conceptual fish passage design for the next six dams (to the Rhode Island/Massachusetts state line).

Task 11 - Formulation of Projects. The Feasibility Study will develop numerous watershed restoration projects to provide fish passage, increase/improve fish and wildlife habitat, etc. The study team and the project sponsor(s) will evaluate all aspects of project implementation including hydrologic, hydraulic, geotechnical, structural, etc. Recreational opportunities should be considered in project formulation although the primary intent of any proposed project shall be environmental restoration or enhancement. Cost estimates will be developed for the selected restoration projects.

Task 12 - Assessment of Project Benefits. Biological benefits will be quantified using a quantitative method, HEP or otherwise. All aspects and disciplines must be considered and evaluated in quantitative form. A cost effectiveness and incremental analysis will be performed to identify economically efficient alternatives.

Task 13 - Prepare Required NEPA, NHPA, and State Environmental Compliance Documentation. The study will prepare any required NEPA documentation for environmental restoration projects proposed for Corps implementation and identify required permits and other significant regulatory issues. The study will also prepare required National Historic Preservation Act (NHPA) compliance documents.

Task 14 - Coordination with USFWS. The study will be coordinated with the USFWS pursuant to the Fish and Wildlife Coordination Act requirements. A fund transfer to the USFWS for a planning aid letter will be required.

Task 15 - Report Preparation.

IX. FEASIBILITY COST ESTIMATE

Once the work effort is identified, a cost estimate is then developed for each of the individual subtasks. A preliminary total cost estimate for the Feasibility phase of the Blackstone River Watershed study is $2,700,000. The final study cost will be dependent on the exact scope of activities which are agreed upon by the Federal government and the non-Federal sponsor(s). The division of costs between the Federal and non-Federal sponsor(s), and the value of sponsor-provided in-kind services, shall be negotiated and the results detailed in the FCSA and PSP.

Blackstone River Watershed Feasibility Investigation

Feasibility Study Cost Estimate

Task 1	**Public Involvement**	$ 25,000
Task 2	**Dams/Ponds Inventory and Assessment**	170,000
Task 3	**Inventory of Habitat Restoration Opportunities**	65,000
Task 4	**Sediments Assessment**	525,000
Task 5	**Hydrological and Hydraulic Studies**	75,000
Task 6	**Topographic and Hydrographic Surveys**	200,000
Task 7	**Water Quality (WQ) Modeling**	295,000
Task 8	**Determine Sediment Loads**	160,000
Task 9	**Assess Options with Respect to Contaminated Sediments** (combined with task 4)	
Task 10	**Anadromous Fish Passage at Dams**	300,000
Task 11	**Formulation of Projects**	610,000
Task 12	**Assessment of Project Benefits**	55,000
Task 13	**Prepare Required NEPA, NHPA, and State Environmental Compliance Documentation**	55,000
Task 14	**Coordination with USFWS**	25,000
Task 15	**Report Preparation**	90,000
	Sub-Total	$2,650,000
	Review Support	50,000
	Total Cost	$2,700,000

June 27, 1997

Projected Number of Projects in the Blackstone River Basin to be Studied in the Feasibility Phase

The following is a list of sites expected to be identified/considered in the Feasibility Study. Assume that 10 percent are selected for preliminary design and cost estimates.

1. Bank stabilization: 20-25 locations, each 500 feet long

2. Instream habitat improvement: 10 new sediment capture ponds
   20 eddy rock placements

3. Riparian restoration: 50 small-scale riparian planting projects
   10-15 riparian gravel pit restorations, each one being 20-40 acres
   10 "brownfields" restorations in otherwise rural settings, each 10 acres

4. Existing ponds used/converted to sediment capture ponds: 25 ponds, all < 5 acres

5. Dredging of large impoundments: 32 ponds of 10 acres each, 5-foot of material dredged

6. Dam repair: 33 dams, 8'-15' height, 1/3 are earthen, 1/3 are masonry, 1/3 are stone based upon existing information and limited field visits. For estimating purposes, let's assume that we will examine 4 dams in a Feasibility-level evaluation, one of which shall include Fisherville Pond Dam in Grafton, Massachusetts.

7. Dam removal: 10 small dams, each < 10 feet high.

8. Small-scale wetland restoration/enhancement with various assortment of tasks including fill removal, ditch removal,construction of check dams, phragmites control: total of 50 sites

9. Studies and report preparation for a 475 square mile river basin

file: numproj.wpd