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Massachusetts
Water
Resources
Commission

1982

North and South Rivers Basin

Plymouth County, Massachusetts

Massachusetts River Basin Planning Program

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PREFACE

The North and South Rivers Basin is located about 15 miles south of Boston and is almost entirely within Plymouth County, Massachusetts. As indicated on the Location Map (Figure I-1), the Basin includes major portions of eight towns and minor portions of an additional four communities. The Basin covers about 73,000 acres or 114 square miles.

The average annual precipitation is about 44 inches. Average annual temperature is about 50° F, with an average in January of about 30° F and in July of about 71° F.

There are two major drainages in the study area; the North River that drains over 50 percent of the area and the South River that drains about 20 percent. Topography is flat and cranberry bogs are an interesting feature of the upper reaches of the Basin.

Towns within the Basin are heavily dependent on groundwater for their municipal water supply. The eight basin towns which comprise the North and South Study Area had a 1980 population of about 108,000. In an average year the basin residents use about 4.9 billion gallons of water.

Plymouth County is important to state and national agriculture. Nationally, it ranks as one of the leading producers of cranberries with production of nearly one million barrels per year. The North and South towns contain about 3,800 acres of land in agriculture use, including 870 acres of productive cranberry bogs.

The Basin abounds with history and many significant cultural, historical, and archaeological features may be found.

More detailed information concerning the Basin and its resource base may be found in Appendix I of this report. Appendix III presents a study of the forest resources of the Basin and Appendix IV contains data regarding the municipal water supply situation in each community.

In June 1978, the Massachusetts Water Resource Commission requested the Soil Conservation Service to develop a Plan of Work for implementing the Massachusetts River Basin Planning Program. The intent of the Massachusetts River Basin Planning Program is to assist small groups of communities in working together to solve intertown or basinwide problems especially in the areas of flooding, water quality, water supply, land use, and recreation. The North and South Rivers Basin is the first basin to be studied under this program. This Basin's water resource problems had been generally identified in the Massachusetts Water Resources Study, a cooperative river basin study completed in 1978 by U.S. Department of Agriculture agencies.

Six of the eight basin towns, along with the Plymouth Conservation District, are sponsors of the study. This local support for the study has provided an excellent opportunity for public participation.

In addition, due to the participation of these communities, the potential for implementing the recommendations of the study (noted in Chapter 3) is much greater.

The study was conducted under authority of Section 6, Public Law 83-566. The Soil Conservation Service, the Economic Research Service, and the Forest Service are the United States Department of Agriculture agencies participating in the study in cooperation with the Massachusetts Water Resources Commission. The major state agency contributing to the study is the Massachusetts Division of Water Resources; others include the Massachusetts Division of Fisheries & Wildlife, Massachusetts Division of Forests & Parks, and the Massachusetts Department of Environmental Quality Engineering. In addition, many local officials and residents of the towns in the Basin actively participated in inventory and advisory activities throughout the planning process.

Chapter 1

PROBLEMS and CONCERNS


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CHAPTER 1

PROBLEMS AND CONCERNS

This chapter outlines the specific North and South Rivers Basin water resource problems and concerns as expressed in meetings with local officials and the general public during the organizational phase of this study. The concerns are:

1. An adequate municipal water supply must be developed to meet projected needs.

2. Groundwater quality must be protected from contamination.

3. Protection and development of stream corridors along those rivers which offer potential for increased recreational use and environmental conservation (the North River, South River, Indianhead River, and French Stream) must be carefully balanced.

4. Sensitive land uses such as wetlands, floodplains, and prime farmland must receive special consideration in community development strategies.

Table 1-1 displays the problems and concerns of this study for selected target years in the future.

Appendix III of this report is a forest resource study that details forest conditions, potential fuelwood yield, residential cordwood use, demands on and harvesting of the forest resource. Because of the extensive treatment of the forest resource in Appendix III, information dealing with the forest resources has not been repeated in the main report. The study of the forest resource did not reveal any severe problems or concerns that could be addressed by project type action.

Likewise, current on-going programs can address effectively the identified erosion and sediment problems within the Basin.

The subject of flooding was investigated in detail by Federal Emergency Management Agency Flood Insurance Study contractors. Nearly 22 percent of the area covered by basin towns is classified as being within the one percent chance floodplain. This relatively large percentage is to be expected given the large area of wetlands within the Basin and the large area subject to tidal influence.

Flood damage to developed property within the Basin has been very high in the past. In 1978, a winter storm resulted in severe damage to homes, roads, and utilities exposed to the fury of the Atlantic ocean. Houses were completely removed from their foundations and tossed about like toys. Whole streets of houses were totally destroyed. Gravel, boulders, boats and docks, and other debris were deposited along streets to a depth of over five feet. Destruction was characterized in newspaper accounts as "unbelievable," fantastic," devastating." In noncoastal areas, flood damage has been minimal.

TABLE 1-1

PROBLEMS AND CONCERNS

Problems and Concerns	Unit	Year 1980	Year 2000 (projected)	Year 2020 (projected)
Quantity of Municipal Water Supply -	Need for Additional Water Supply (Expressed in millions of gallons per day).			
Duxbury		0.2	1.8	3.1
Hanover		Surplus	Surplus	0.5
Hanson		0	Surplus	Surplus
Marshfield		0.4	2.4	3.9
Norwell		Surplus	0.6	1.2
Pembroke		0	1.0	1.7
Rockland		1.1	2.2	3.6
Scituate		1.1	1.4	2.2
Quality of Municipal Water Supply- (Preservation of municipal water quality)	Not quantified	Water quality problems noted in seven of the eight basin communities.	Increasing problems expected if action is not taken to protect aquifers and recharge areas from contamination.	
Protection and Development of Stream Corridors	Regional 1/ Recreation Needs			
	Motor Boating (water acres)	463,000	516,000	
	Sailing/Canoeing (water acres)	22,000	23,000	
	Camping (sites)	2,400	2,200	
	Fishing (water acres)	14,000	16,000	
	Picnicking (tables)	24,000	28,000	
	Hiking (trail miles)	53	80	
	Nature Walking (trail miles)	1,250	1,450	
Conservation of Areas Sensitive to Development, Especially: Prime Farmland Soil; Wetlands; Aquifer Recharge Areas; Floodplains; Soils with Limitations for Disposal of Septic Tank Effluent	Population (Increased population will increase developmental pressure on sensitive areas)	107,600	124,500	126,200

1/ Needs for Region VIII (Metropolitan Boston) from "Massachusetts Outdoors," Statewide Comprehensive Outdoor Recreation Plan, Massachusetts Department of Environmental Management, Boston, 1978. Although the data relate to the entire Metropolitan Boston recreational region, the existence of tremendous unmet recreational needs indicates potential demand that will put pressure on the recreational resources of the North and South Basin.

In view of the nature of the flood damage--high levels of coastal damage, low levels of other flood damage--it was determined that no locally acceptable plan to significantly reduce flood damage could be formulated. Much of the damagable property is exposed to the full force of the ocean waves and no reasonable structural measure could protect such property. Nonstructural measures such as flood proofing would be ineffective against storm surges. Floodplain reclamation involving moving houses and facilities away from the area would be unacceptable to the affected residents and local government.

1. Water Supply

The adequacy of the developed sources of municipal water supply was identified as an area of concern in the initial phase of this study. The concern is natural given the importance of an adequate water supply to the health, well-being, and future of the communities. Local governments in Massachusetts have traditionally been responsive to citizen demands for an ample municipal water supply.

Each of the basin communities operates its own independent water distribution system, but intertown cooperation is a common practice. Outlying areas of several communities are served by the municipal water systems of adjacent towns.

Per capita use of water varies from 65 to over 100 gallons per day in the eight towns. Usage at this rate is not unusual considering the residential nature of the area and the lack of large-scale industrial uses of water.

Appendix IV of this report presents a detailed analysis of the municipal water supply situation in the Basin. Information for each community is included for the following topics:

a. Present conditions including data on population served, developed water supply sources, system safe yield, and conservation measures undertaken by the town. These data were obtained through interviews with water department officials and from survey forms completed by water department superintendants under requirements of the state's Municipal Water Resource Management Plan, in addition to previous studies completed by consultants and state and federal agencies.

b. Projections of future demand for the years 1990, 2000, 2010, and 2020 were developed utilizing population projections and projected per capita demand. Estimates of future demand for water have been computed on the basis of a one percent increase in per capita demand each year.

c. Projected demand for each of the years under consideration was compared with the developed safe yield of the town to determine the need for additional municipal water resource development.

d. Many towns in the Basin have conducted studies to locate potential water supply sources. The results of the studies are presented with a summary of recommendations from the reports.

e. An evaluation of the groundwater resources of the towns with emphasis on geology, potential groundwater hazards, and possible additional sources of supply is presented.

The analysis of projected water supply needs detailed in Appendix IV indicates that five of the eight basin towns are faced with municipal water demands projected to exceed the safe yield of developed sources by the year 1985. By the year 2000, only Hanover and Hanson will be able to meet projected demand using present resources; all except Hanson will have demand exceeding current developed supply by the year 2020.

If the communities are to continue to meet their obligations to provide an adequate potable water service, steps need to be taken in the near future in order to insure a municipal supply capable of meeting projected demands.

2. <u>Water Quality</u>

In the North and South Rivers Basin every town utilizes groundwater to some extent. (Hanson will begin using wells in October 1982). Five of the eight communities rely entirely on groundwater to meet municipal water demands. In view of this dependence on the groundwater resources, the maintenance of groundwater quality was identified as an area of concern for this water resources study.

Problems with groundwater quality have varied within the communities. In 1978, Hanover declared a moratorium on new construction in the area of Route 53 so that a groundwater protection strategy could be developed for this area that overlies the primary groundwater aquifer in the community. Scituate was forced to abandon a well because of groundwater contamination from a nearby disposal site. Increasing sodium levels, apparently caused by road salting, are a concern in several towns. Table 1-2 summarizes Basin municipal water quality problems.

Table 1-2

Water Quality Problems in Basin Towns

Town	Water Quality Problems
Duxbury	Corrosion
Hanover	Iron, manganese, color,
Marshfield	Sodium
Norwell	sodium
Pembroke	Low pH, iron
Rockland	Iron, manganese, color
Scituate	Manganese, hardness, iron

As cases of groundwater contamination are reported from other areas of Massachusetts and groundwater sources are declared unsuitable for municipal use, concern for the protection of groundwater quality has increased in the North and South Basin. Specific concerns include the protection of aquifers from contamination and the identification and protection of primary aquifer recharge areas.

Residential land use can produce both short- and long-term effects on water quality and quantity. Quantity of runoff infiltrating into the ground is reduced by the paving-over effect of urbanization. Quality of groundwater can be impaired by the introduction of sewage from septic systems. Compounds of nitrogen and phosphorous are introduced into groundwater from effluent and may lead to groundwater pollution. Percolation of septic tank effluent through unsaturated soil removes bacteria, organic matter and viruses by filtration, biological decay and adsorption. The dissolved inorganics like nitrates and chlorides may pass on through the unsaturated zone to the water table. Pesticides, herbicides and fertilizers may infiltrate into the ground or can become a part of the urban runoff.

A secondary by-product of residential development is the production of sediment from construction activities. Sediment accumulation in river and lake bottoms can decrease the potential for induced infiltration into aquifers.

Agricultural activities have the potential for groundwater contamination. Pollutants can be derived from improper storage and use of manure, fertilizers and agricultural chemicals. To address pollution from these sources, on-site measures are required.

Resource management systems for managing fertilizer and manure to protect, maintain, or improve water quality have been developed by the Soil Conservation Service and are available to interested farmers through the Raynham Field Office.

Associated with highway runoff is road salting, one of the greatest potential and existing pollution problems facing towns throughout Massachusetts. Sodium chloride and calcium chloride applications have resulted in elevated levels of sodium in groundwater supplies. Many salt pollution cases can be cited from the literature.

3. Stream Corridor Development

Stream corridors can provide features that promote a satisfying environment while serving the needs of people for open space. The concerns in examining stream corridor resources are related to identifying, developing, and managing a network of corridors according to standards that curtail pollution and siltation, reduce the hazard of flood losses, provide quality recreation areas, promote high scenic quality, and protect other important resource systems.

Some of the most significant natural resources are concentrated in linear patterns within and along the confines of a stream valley. Watercourses, wetlands, floodplains, aquifers, important wildlife habitats, historic sites, and areas of high scenic quality may often be combined into a system with fairly distinct boundaries. Such a system could be considered the least tolerant to development because of its resource value, scenic character, recreational importance, and long-term economic value in preserving the quality and quantity of water supply. Public policy has often called for retaining such areas in their open space condition. The North and South Rivers corridors have been viewed for some time as a local open space system and recreation resource. However, this area has recently gained attention as a regional open space system for serving some of the increasing recreational demands of the Boston Metroplitan Area. Because of this, there is increasing local concern that the aesthetic and resource qualities existing in the stream corridors could be impaired by excessive public use. Perceived negative aspects of greater public use include degradation of resource values, diminution, or loss of scenic character, increased noise, and the threat of vandalism, congestion, and parking problems.

Basin communities are concerned about these pressures from outside the Basin, whose effect on the stream corridors is uncertain. Local objections have been expressed toward using the stream corridors for the intensity of public use that the demand indicators predict. Town boards and commissions have reacted to this concern by developing legal and managerial strategies for directing and locating future development (including residential and commercial buildings, subdivisions, as well as picnic areas, boat launching ramps, and other recreational features) to areas that would not jeopardize the existing resource character of their respective communities.

Because of these concerns, the future of the river corridor includes numerous legal, managerial, and aesthetic conflicts in the face of increasing population pressures. Over the past two to three decades, the dual increase in recreational use and residential development of the river corridors has created several apparent conflicts. One conflict arises between residents desiring an undisturbed view of the rivers and recreationists desiring greater use and access to the rivers.

Conflicts also exist among recreationists themselves arising largely from conflicting activities, such as the use of motorized boats on the river corridors and nonmotorized and passive recreational activities. Motorized boats have been cited as accelerating bank erosion through increased water turbulence and causing degradation of water quality via oil, gasoline, and sewage discharge. Swimming, fishing, and passive water-based activities are also affected by the heavy use of motorized boats. Towns along the North River, where most of these conflicts exist, have reacted to these problems with legislative measures. Scituate and Marshfield, for example, have imposed speed limits and "no-wake" requirements, and have banned water skiing on the North River; however, effective enforcement of these regulations has been difficult.

4. Areas Sensitive to Development

Areas sensitive to development include land or water areas which are serving an important production or protection function for the community, or areas that present severe limitations to development. In the North and

South Rivers Basin, the areas considered to be most sensitive to development include: soils with limitations for disposal of septic tank effluent, prime farmland soils, wetlands, primary aquifer recharge areas, and flood plains.

Inappropriate use of such areas can lead to loss of an irreplaceable resource or to an increase in public and private costs to correct the negative impacts. In planning for the conservation of sensitive areas, consideration must be given to the indirect effects of adjacent land use changes as well as the direct effect of development on these areas. If overriding development needs require alteration of a sensitive area, appropriate management measures to minimize the negative impacts of the alteration should be utilized.

a. <u>Soils with Limitations for Disposal of Septic Tank Effluent</u>

The septic tank and leach field comprise a relatively simple and efficient method to dispose of potentially hazardous human waste while returning water to the soil. The septic tank is designed to receive household sewage; remove, partially decompose, and store solids; and to discharge a liquid which is more suitable for final treatment by soil absorption systems. The use or economy of septic tanks and leach fields as a sewage disposal method is limited by particular soil characteristics such as a high water table, a fragipan, a perched seasonally-high water table, layer with low permeability, bedrock close to ground surface, and steep slopes. High water tables pose a hazard since septic tank effluent can quickly reach the groundwater before the effluent has an opportunity to percolate through the soil layer for a long enough period to allow bacterial action to occur. Slowly permeable layers limit the quantity of effluent that can be absorbed and may result in effluent appearing on the ground surface. The presence of bedrock close to the surface and steep slopes can greatly increase the cost of installing a disposal system and may contribute to ineffective system operation.

Table 1-3 presents data concerning the extent of soils with limitations for disposal of septic tank effluent. The data indicate that a large percentage of each community's total area has limitations that need to be considered before development takes place and problems develop.

Table 1-3

Area of Soils with Limitations for Septic Systems (ACRES)

Town	Limiting Soil Characteristic: High Water Table	Fragipan & Perched Seasonally High Water Table	Slowly Permeable Layer	Bedrock Close to Surface or Steep Slopes	Total of Areas with Limitations	Total Area in Town	Percent of Town with Limitations
Duxbury	4370	140	150	550	5210	15,450	34
Hanover	3950	590	620	330	5490	9,980	55
Hanson	3970	1720	240	370	6300	9,970	63
Marshfield	6450	2270	530	1430	10680	18,680	57
Norwell	5020	3410	980	390	9800	13,130	75
Pembroke	4420	960	620	1080	7080	15,280	46
Rockland	2410	680	130	250	3470	6,420	54
Scituate	3910	3780	540	670	8900	11,280	79

b. Prime Farmland Soils

Prime farmland is land best suited for producing food, feed, forage, and fiber; and also available (or potentially available) for those uses. The land could be cropland, pastureland, forestland, or other land, but not urban, developed land, or waste disposal areas. It has the soil capability, growing season, and moisture supply needed to produce sustained high yields of crops economically when treated and managed, including water management, according to modern farming methods.

Throughout the nation and especially in relatively densely populated states such as Massachusetts, the nearly irreversible loss of prime farmland to urban uses is an issue of increasing concern. As farmland, and potentially available farmland, is converted to houselots, shopping centers, and other urban-type uses, Massachusetts consumers become more dependent upon other states and nations to meet our basic needs for food. Developers favor prime farmland because many of the factors that make farmland prime also make prime building sites. Gentle slopes, lack of stones, good drainage, and good soil depth all favor development as well as farming. Table 1-4 presents data concerning the conversion of areas of prime farmland soil to urban use in the period 1970-1980.

Table 1-4

Potentially Available Prime Farmland Soil
(ACRES)

Town	1970	1980	Loss (1970-1980)	Percent Loss
Duxbury	860	640	270	31
Hanover	1050	780	270	26
Hanson	810	670	140	17
Marshfield	1470	960	510	35
Norwell	940	790	150	16
Pembroke	1280	960	320	25
Rockland	210	140	70	33
Scituate	390	290	100	26

Norman Berg, former Chief of the Soil Conservation Service, warned that "ten years from now, Americans could be as concerned over the loss of the nation's prime and important farmlands as they are today over shortages of oil and gasoline." Today, there are highways and houses, airports and shopping centers on land that once produced an abundance of agricultural products.

Farmland that vanishes in the wake of urban sprawl is unlikely to be utilized for agriculture again. "When pastures become parking lots, when houses crowd the land where corn once grew, the loss to agriculture is irreversible. Cloak fertile fields in steel, asphalt, and cement, and there is no turning back. The farmland is gone forever."

c. Wetlands

Wetlands are those areas where the water table is at or near the ground surface for much of the year and which are subject to occasional flooding. Wetland areas are important because they can function as natural floodwater storage areas, provide valuable wildlife habitat for a variety of species, maintain summer streamflow, serve as groundwater recharge areas, and provide recreational opportunities such as fishing, hunting, and nature study.

The value of wetlands has been recognized by the Commonwealth and legislation has been enacted to protect wetlands against loss to development. The Wetlands Protection Act requires the approval of the local conservation commission before a wetland can be altered. The Wetlands Restriction Act (General Laws Chapter 131) provides a mechanism to establish deed restriction to protect wetland areas. Section 105 of Chapter 131 authorizes restrictions on coastal wetlands and restrictions are in effect in the basin towns of Duxbury, Hanover, Norwell, and Pembroke.

Table 1-5 provides data on the area of wetlands in the Basin.

Table 1-5

Wetland Areas in the North-South Basin Towns
(ACRES)

Town	Wetland Area	Water Area	Total	Percent of Town
Duxbury	2870	1140	4010	26
Hanover	2890	100	2990	30
Hanson	2740	520	3260	33
Marshfield	4980	630	5610	30
Norwell	3940	260	4200	32
Pembroke	3120	1360	4480	29
Rockland	1250	50	1300	20
Scituate	2720	600	3320	29

d. Primary Aquifer Recharge Areas

Groundwater is the dominant source of municipal drinking water in the North and South Rivers Basin. As a result, the areas that serve to recharge the groundwater aquifers meet the definition of areas sensitive to development since development could reduce infiltration to the aquifers and also pose a threat of groundwater contamination.

e. Floodplains

The floodplains of the North and South Rivers Basin are areas sensitive to development as they present severe limitations to development. Floods and the resulting damage to property are well documented. Undeveloped floodplain land is best left in its natural state or if developed, the new land use should be compatible with the flood hazard. Table 1-6 indicates the extent of floodplain land in the basin communities.

Table 1-6

Flood Plain Land
(ACRES)

Town	Flood Plain Area	Percent of Town Area
Duxbury	4,000	26
Hanover	2,150	22
Hanson	500	5
Marshfield	6,300	34
Norwell	3,000	23
Pembroke	1,540	10
Rockland	650	10
Scituate	3,510	31

f. Summary

The preceding discussions of the various categories of land sensitive to development indicated that significant portions of the basin towns are included. Some parcels of land are sensitive to development because of many reasons; for example, a wetland area has severe limitations for disposal of septic tank effluent and might also be in a flood plain while serving as a primary aquifer recharge area. Other primary recharge areas or parcels of prime farmland soils might be sensitive to development for only one reason.

This is not intended to suggest that development should be prohibited in all of the areas, but that special consideration should be given to the nature of the sensitive areas relative to the proposed development.

Table 1-7

Summary of Development-Sensitive Areas

Town	Percent of Town in Each Category*			
	Limitations for Septic Tanks	Wetland Areas	Flood Plain	Prime Farmland Soil
Duxbury	34	26	26	4
Hanson	55	30	22	8
Hanover	63	33	5	7
Marshfield	57	30	34	5
Norwell	75	32	23	6
Pembroke	46	29	10	6
Rockland	54	20	10	2
Scituate	79	29	31	3

*Total percent in each town may total more than 100 percent as some land may be counted twice; i.e., flood plain may also be wetland and have limitations for septic tanks.


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Chapter 2

RECOMMENDED PLAN


NORTH
RIVER

CHAPTER 2

RECOMMENDED PLAN

1. Implement water conservation measures to maintain present per capita consumption rates through the year 2000 and reduce per capita consumption by ten percent by the year 2020.

2. Supplement water conservation measures with water resource development that favors identified groundwater alternatives.

3. Implement groundwater protection bylaws to regulate land use for the protection of primary aquifer areas.

4. Conduct periodic pressure tests and monitor petroleum storage tanks located near municipal wells to detect leaks and suggest corrective action, if problems are found.

5. Limit the application of road de-icing salt to that required to maintain highway safety. Special consideration should be given to state highways crossing aquifer recharge areas.

6. Continue support of the activities of the North River Commission.

7. Encourage development of additional public access to the river corridors for hikers, canoes, and small boats.

8. Encourage inter-town cooperation to establish consistant zoning protection of stream corridor resources.

9. Adopt regulatory measures and preservation techniques to ensure that development-sensitive areas are adequately protected.

Formulation of this "Recommended Plan" was based on suggestions received from local, state, and federal agencies in response to a circulated review draft, and from comments and suggestions received at a series of three public meetings conducted within the Basin in April 1982, which were attended by representatives of five of the basin towns and two state agencies.

The plan contains elements selected to meet identified needs within the specific water resource problems and concerns of the basin towns. The plan elements are selected from the alternatives presented in Chapter 4 and comprise a series of recommendations that appear to be both politically and environmentally acceptable, as well as being implementable under existing legislative and regulatory constraints.

Problem or Concern:

An adequate municipal water supply must be developed to meet projected needs.

Recommended Plan Elements:

Implement water conservation measures intended to reduce present per capita consumption by ten percent by the year 2020.

Supplement conservation measures with water resource development favoring identified groundwater alternatives.

Discussion:

Historically, the per capita demand for water has been increasing as more families install water-using appliances such as dishwashers, automatic washers, and garbage disposals, and acquire more cars that are washed and swimming pools that need to be filled. Even with a stable population, total water consumption is expected to increase.

Water conservation measures offer the potential to halt the increase in per capita demand and in some cases to reduce present demand. Studies indicate that water conservation techniques might be expected to reduce consumption by a maximum of 16 percent. However, given the residential nature of the North and South Basin towns, and the lack of a significant water-using industrial base, the maximum reduction in demand expected from conservation measures is about ten percent. Even this reduction would be difficult to achieve immediately and would require years of public education and development of a water conservation ethic among water users.

A realistic goal for an intensive water conservation program of public education, regulatory measures, and physical modifications would be to expect that per capita demand could be maintained at present levels through the year 2000 and would be gradually decreased by ten percent by the year 2020.

Even with an extensive water conservation program, some of the basin towns will not be able to supply the required quantity of water without developing additional sources. Geology and topography of the North and South Basin favor the development of groundwater resources vis-a-vis surface sources. Water departments have more extensive experience with the operation and maintenance of groundwater systems and state regulatory agencies prefer groundwater development. For these reasons, the Recommended Plan gives emphasis to development of identified groundwater alternatives where practical.

Specific recommendations for individual towns are outlined below. In most cases, the recommended measures were identified by preliminary studies conducted by private consultants and state and federal agencies. Detailed engineering studies will be needed to assess the suitability of the selected option and to determine the costs (financial and environmental) of development. In addition to conservation measures, the following additions to developed capacity are suggested:

Duxbury - Develop three wells investigated by Whitman and Howard Consulting Engineers. The wells will need to provide a combined minimum safe yield of 1.0 million gallons per day.

[illegible]

[illegible]
[illegible]
[illegible]
[illegible]

[illegible]
[illegible]

Hanover - Conservation measures, if adopted, would result in a supply adequate to meet needs through the year 2020.

Marshfield - Develop two wells which in combination would provide a minimum safe yield of 1.2 million gallons per day in the aquifers identified in the Goldberg-Zoino-Dunnicliff Groundwater Resources Inventory.

Norwell - Develop a surface reservoir providing at least 0.3 million gallons per day. Investigate reservoir sites SS-2703 and SS-2750.

Pembroke - Develop a well to provide at least 0.6 million gallons per day--location undetermined. Alternatively, investigate reservoir site SS-2716.

Rockland - Expand Hingham Street reservoir to provide an additional 0.5 million gallons per day safe yield. Pursue an intensive geohydrologic study of aquifer to locate potential sources for an additional 1.2 million gallons per day safe yield.

Scituate - Develop surface reservoir on First Herring Brook. Investigate purchase of water from Cohasset.

Problem or Concern:

Groundwater quality must be protected from contamination.

Recommended Plan Elements:

Implement groundwater protection bylaws to regulate land use for the protection of primary aquifer areas.

Periodically pressure test and monitor petroleum storage tanks located near municipal wells to detect leaks and indicate the need for corrective action.

Limit the application of roadway de-icing salt to that required to maintain highway safety. Special consideration and monitoring is needed where major state highways cross aquifer recharge areas.

Discussion:

Protection of groundwater quality must be based on accurate knowledge of the extent of primary aquifers and aquifer recharge areas. Such knowledge is developed by conducting a detailed and comprehensive examination of the hydrogeology of the area. Various levels of intensity have been used by consultants and state and federal agencies to define the extent of aquifers and recharge areas in the Basin.

Five of the basin towns have some form of aquifer protection. Hanover has gone the farthest toward a groundwater protection bylaw. Pembroke, Hanson, and Rockland have no formal groundwater protection programs. Because of the high level of dependence on groundwater, all of the basin communities should place priority emphasis on groundwater protection strategies.

Problem or Concern:

Protection and development of stream corridors along the North River, South River, Indianhead River, and French Stream.

Recommended Plan Elements:

Continue support of the activities of the North River Commission.

Encourage the development of additional public access to the river corridors for hikers, canoes, and small boats.

Explore inter-town cooperation to establish consistent zoning protection of stream corridor resources.

Discussion:

The Protection Order for the North River, developed under the Scenic and Recreational Rivers Act, authorizes regulation of development within the North River corridor. The Order prohibits use that would be adverse to the natural visual quality of the area. Representatives from each town along the river comprise the North River Commission that administers the Protection Order.

As a demonstration project for the Scenic and Recreational Act, the Protection Order deserves continued local government support to ensure that the Order has a fair chance to prove its value in protecting the visual quality of the river corridor.

Intensive public use of the rivers is a topic of continuing debate among local residents. There is a reluctance to embark on large scale recreation development but there is a willingness to see limited development of a passive recreation nature. Such uses as hiking trails along the river, launch areas for rowboats and canoes, and access points for nature study would receive local support. Improved access for power boats, swimming, and large picnic areas would meet local resistance.

Basin communities have initiated zoning measures to protect water resource related areas from development. Zoning ordinances, as well as permitted and prohibited uses have not been consistent throughout the corridors, resulting in a need for inter-town coordination to ensure protection of those resources that transcend municipal boundaries.

Problem or Concern:

The land resource base has a number of sensitive land uses such as wetlands, floodplains, and prime farmland that need special consideration in any community development strategy.

Recommended Plan Elements:

Make increased use of regulatory measures and preservation techniques to ensure that development-sensitive areas are adequately protected.

Discussion:

A wide variety of measures and techniques is available to the basin towns to assist in the protection of sensitive areas. Among the options are:

Protective zoning including special zones to conserve floodplains, wetlands, agricultural land, municipal watersheds, and groundwater; Chapter 40A, Massachusetts General Laws.

Subdivision regulations that recognize and enhance environmental values.

Tax incentives.

Use of the Plymouth County soil survey and effective percolation testing.

Purchase of development rights to agricultural land; Chapter 780, Massachusetts General Laws.

Assessment of farmland under the Agricultural and Horticultural Assessment Act; Chapter 61A, Sections 1-24, Massachusetts General Laws.

Assessment of forestland under the Forest Assessment Act; Chapter 61, Sections 1-7, Massachusetts General Laws.

Control of wetland alteration under the Wetlands Protection Act; Chapter 131, Section 40, Massachusetts General Laws.

Restriction of wetland development through the Wetland Restriction Act, Chapter 130, Section 105, Massachusetts General Laws.

Control of floodplain development under requirements of the National Flood Insurance Program.

These options have been used to varying extents by the eight towns and offer a good basis to formulate a protection strategy consistent with local desires, needs, and practices.

Table 2-1 presents a display of the effects of each plan element on four accounts: national economic development, environmental quality, regional economic development, and other social effects.

Table 2-1

Display of Plan Element Effects

Plan Element	National Economic Development	Environmental Quality	Regional Economic Development	Other Social Effects
1. Implement water conservation measures to maintain present per capita consumption rates through the year 2000 and reduce per capita consumtion by ten percent by the year 2020.	Beneficial Effects Developed water resources will meet the needs of a larger population. Adverse Effects Cost of program implementation.	Beneficial or Adverse Effects Demand reduction will substitute for the need to develop additional resources.	Beneficial Effects Developed water resources will meet the needs of a larger population.	Beneficial or Adverse Effects Increased public awareness of the importance of municipal water supply.
2. Supplement water conservation measures with water resource development that favors identified groundwater alternatives.	Beneficial Effects Water supply will be available to meet needs from community growth. Adverse Effects Cost of water resource development.	Groundwater development will have minimal environmental effects. Some towns will need to develop surface water resources. Environmental impact assessments will be required.	Beneficial Effects Water supply will be available to meet economic growth demands of the region.	
3. Implement groundwater protection bylaws to regulate land use for the protection of primary aquifer areas.	Beneficial Effects Developed groundwater resources will be protected.	Groundwater quality will be protected.	Beneficial Effects Developed groundwater resources will be protected. Adverse Effects Less land available for industrial and commercial development.	
4. Periodically pressure test and monitor petroleum storage tanks located near municipal wells to detect leaks and indicate the need for corrective action.	Adverse Effects Pressure testing costs may be $200 to $500 per tank.	Groundwater quality will be protected.	Adverse Effects Pressure testing costs may be $200 to $500 per tank. Tank owners in adjoining regions may benefit from avoidance of this cost.	Increased public safety aspect from periodic testing of flammable liquid tanks.
5. Limit the application of road de-icing salt to that required to maintain highway safety. Special consideration should be given to state highways crossing aquifer recharge areas.	Beneficial Effects Developed groundwater resources will be protected. Lower salt costs. Adverse effects Higher sand and application costs; possibly higher accident costs.	Groundwater quality will be protected. Increased use of sand instead of salt may result in increased sediment delivery to streams.		
6. Continue support of the activities of the North River Commission.		Scenic and visual quality of North River corridor will be protected.		Success with the North River pilot project will improve prospects for similar Protective Orders for other state rivers.
7. Encourage development of additional public access to river corridors for hikers, canoes, and small boats	Beneficial Effects Provide recreational opportunities. Adverse Effects Cost involved in implementing program.	Increased public awareness of resource.		Some landowners may be adverse to recreational development near their property.
8. Explore inter-town cooperation to establish consistent zoning protection of stream corridor resources.		Increased protection of natural resource value of the stream corridors.		Inter-town coordination on stream resource zoning could lead to cooperation in other areas of common interest.
9. Make increased use of regulatory measures and preservation techniques to ensure that development-sensitive areas are adequately protected.		Increased protection of areas sensitive to development. More open space and undeveloped areas.	Adverse Effects Less land available for industrial, commercial, and residential development. Lower tax base.	Undeveloped areas will counteract urban areas and preserve suburban character of the area.

Comparison of Plan Elements and Needs

In the area of water supply, the implementation of an aggressive water conservation program combined with selective development of identified alternatives should enable the basin towns to meet municipal water demands through the year 2020.

Quantification of the effects of other plan elements upon the needs in each area of problems and concerns is difficult because of the many scenarios that might develop. For example, in the area of water quality protection, several problems have been identified. However, existing zoning regulations, limitations of road salting, and a projection of low population growth may combine to slow the threat of groundwater contamination. Likewise, a change in population figures, several severe winters, or an "irresistable" industrial or commercial development could worsen the threat. Most of the plan elements will serve to formalize the protection of the natural resource base but will not have a readily quantifiable effect on resource protection without the presence of a quantified threat to the resource.

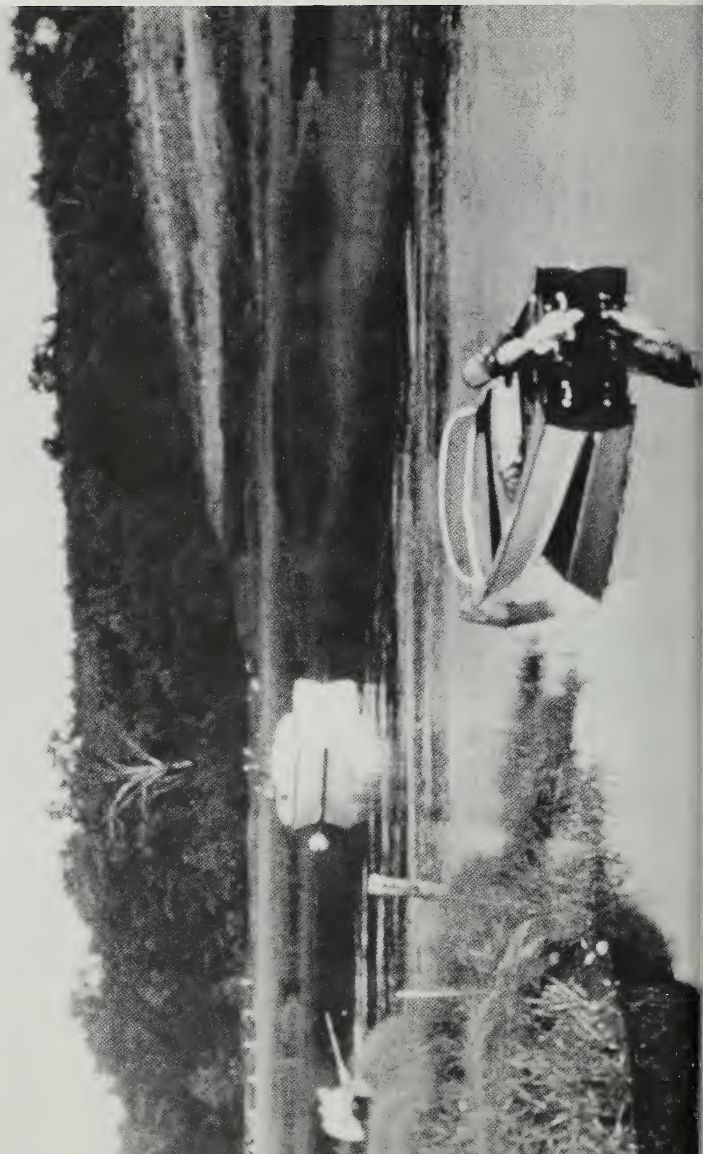
Environmental Effects of Plan Elements

Table 2-1 displays the effects of plan elements upon environmental quality. Since many of the elements were specifically selected to protect and enhance the natural resource base, the effects could be characterized as being predominantly beneficial.

The environmental impact of the Recommended Plan within the Basin is summarized in Table 2-1. The impact outside the basin area is expected to be minimal.

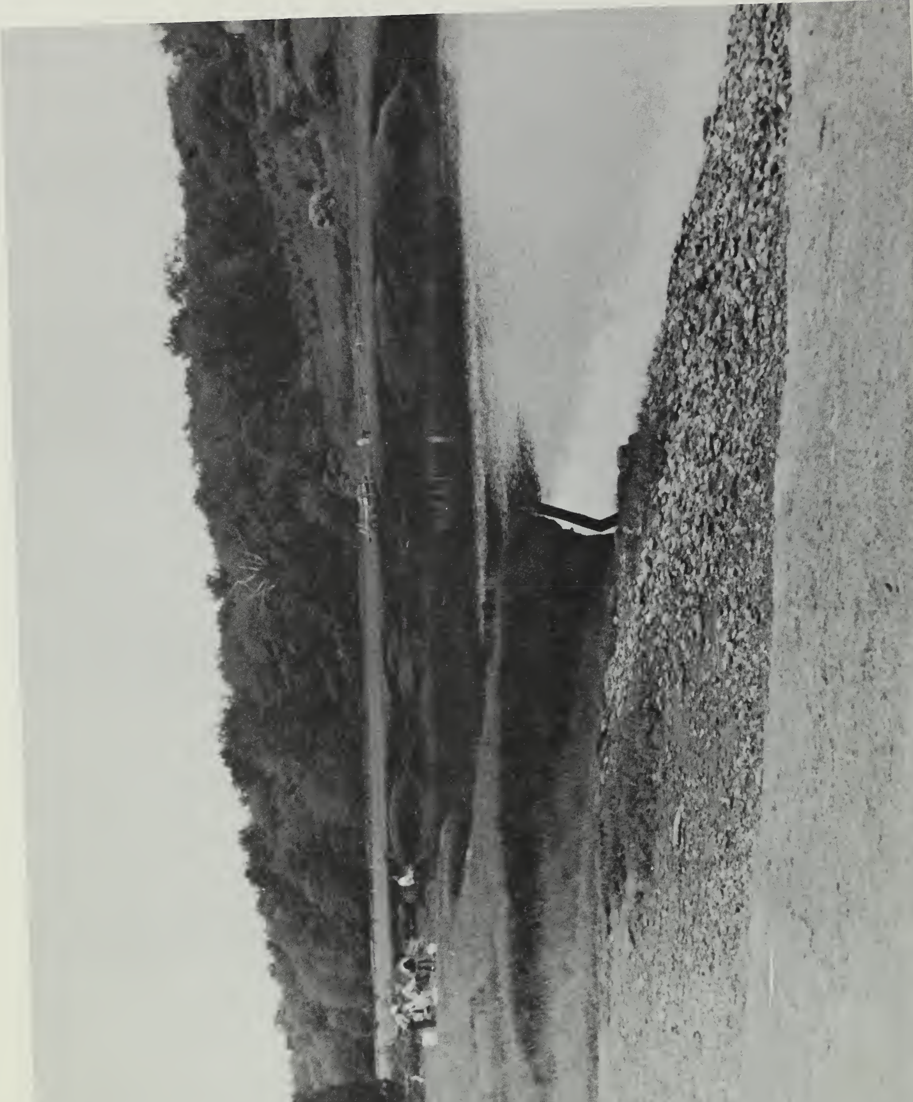
Plan elements coordinate with or complement existing land use plans, policies, and controls for the affected area. Several elements recommend the strengthening of existing land use controls to ensure protection of specific resources. No new state or federal legislation or programs will be required to implement the elements.

Chapter 4 details the alternatives studied during the evaluation and analysis phase of this study. These alternatives formed the basis for discussion and comment during the review period and during the public meetings held within the Basin. Implementation of the plan elements is expected to have long-term beneficial effects on the environment.



Chapter 3

OPPORTUNITIES for IMPLEMENTATION



CHAPTER 3

OPPORTUNITIES FOR IMPLEMENTATION

This chapter identifies agencies, groups, and organizations that could take leadership to implement portions of the recommended plan. Further discussions include various federal, state, and local programs that might directly affect problems that are of concern in this study. Some plan elements can be implemented through various programs; the opportunities outlined in this chapter present some, not all, possibilities for implementation.

Plan Element: Implement water conservation measures intended to maintain present per capita consumption rates through the year 2000 and reduce per capita consumption by ten percent by the year 2020.

Opportunities for Implementation: Mechanized devices, institutional arrangements, consumer education, and a positive cooperative attitude are required for a successful water conservation program. Local government holds the key to ensuring success in water conservation.

An extensive ongoing public information campaign is needed if desirable public attitudes toward water conservation are to be developed. Basin residents have viewed the municipal water supply as an inexpensive boundless resource that can be exploited. If this viewpoint is to change, local government needs to keep the conservation message in the minds of the water users through reminders enclosed with municipal mailings, news articles, radio and television announcements, and school programs. Water conservation relies on actions taken in individual homes and businesses and requires a user group that is convinced of the need and benefits achievable through conservation.

Municipal governments can also ensure that institutional arrangements encourage conservation. Universal metering of water use and water rate structures that discourage excessive use are two examples of institutional measures that can be employed.

The Massachusetts State Building Code mandates water conserving devices in new construction. Strict enforcement of the Code will assist the towns in their efforts to limit per capita use of water.

Plan Element: Supplement conservation measures with water resource development favoring identified groundwater alternatives.

Opportunities for Implementation: In this element also, the local town governments bear the primary responsibility for implementation.

The Farmers Home Administration, an agency of the U.S. Department of Agriculture, makes loans and grants to small communities for water and waste disposal improvements. In addition to financial aid, the Farmers Home Administration provides technical and management assistance. Financial and technical assistance is limited to communities below 10,000 population; the towns of Hanson and Norwell are in this category.

The Division of Water Resources of the Department of Environmental Management has funds available from a bond issue to acquire and protect potential reservoir sites. Funds may also be available from this source to investigate and protect potential surface water reservoir sites.

The Massachusetts Self-Help Program can assist communities with the acquisition of water supply sites and can also assist by acquiring conservation lands for future use as water impoundments.

Plan Element: Implement groundwater protection bylaws to regulate land use for the protection of primary aquifer areas.

Opportunities for Implementation: The implementation of zoning bylaws is a municipal function borne by local government. The town of Hanover has accomplished the most toward aquifer protection of the eight basin communities. Other towns could make use of the Hanover experience to avoid pitfalls and obstacles to bylaw implementation. Regional planning agencies (Metropolitan Area Planning Council and Old Colony Planning Council) may be able to provide assistance in the drafting of aquifer protection bylaws.

Plan Element: Periodically pressure test and monitor petroleum storage tanks located near municipal wells to detect leaks and indicate the need for corrective action.

Opportunities for Implementation: Implementation of this recommendation requires local action. Periodic pressure testing of tanks could be performed by a local agency (health, planning, fire, etc. department) or contracted to a private firm. Testing might be made a requirement for storage permit renewal in areas of especially high potential for groundwater contamination. Replacement of metal storage tanks with corrosion-resistant tanks (fiberglass, for example) is also encouraged.

Plan Element: Limit the application of roadway de-icing salt to that required to maintain highway safety. Special consideration and monitoring is needed where major state highways cross aquifer recharge areas.

Opportunities for Implementation: Implementation of this element requires action by state and local agencies. Town highway departments need to be made aware of the location of aquifer areas that may be especially susceptible to contamination from highway runoff containing de-icing salt. Likewise, the Massachusetts Department of Public Works needs to be made aware of potential hazard areas located along the state highway system. Chapter 4 of this report contains an aquifer protection alternative that details specific locations that should be considered for salt limitations.

Plan Element: Continue support of the activities of the North River Commission.

Opportunities for Implementation: The North River Commission consists of a representative and alternate from each of the towns of Hanover, Hanson, Marshfield, Norwell, Pembroke, and Scituate. Among other things, the Commission has the responsibility to manage and carry out the Scenic and Recreational River Protective Order for the North River; review applications and grant, deny, or condition special permits; investigate violations of the Order; and implement the North River Management Plan.

The Protective Order was adopted to protect public and private property, wildlife, freshwater fisheries, and irreplaceable wild, scenic, and recreational river resources. The North River was selected as the pilot project under the Scenic and Recreational Rivers Act passed by the Massachusetts legislature in 1971. The Protective Order details allowed uses within the North River corridor as well as special permit uses and prohibited uses.

Continued local support of the North River Commission is essential to the success of the Protective Order in protecting the North River corridor.

Plan Element: Encourage the development of additional public access to the river corridors for hikers, canoes, and small boats.

Opportunities for Implementation: The Soil Conservation Service is the lead USDA agency for the Pilgrim Resource Conservation and Development Area which includes all of the basin communities. The RC&D Area was established to "improve the quality of life in the area through a coordinated effort to provide local decisionmakers with technical information and financial aid for action-oriented measures, which seek to better utilize, manage, and protect the area's unique natural resources." The RC&D program can provide financial and technical assistance measures for public water-based recreation and fish and wildlife development. Assistance from the RC&D program could provide the necessary technical assistance to plan the development of acceptable means of additional public access to the river corridors.

A Measure Plan developed for the Nemasket River in Lakeville and Middleborough includes a nature trail, installation of three canoe accesses, and a rest area. Similar low intensity development could be investigated for implementation in the North and South Basin.

Plan Element: Explore inter-town cooperation to establish consistent zoning protection of stream corridor resources.

Opportunities for Implementation: The planning boards of the eight towns are encouraged to explore inter-town coordination of their zoning bylaws to ensure that stream corridor resource protection is consistent across town lines. Such coordination will help ensure that weak or inadequate zoning in one community does not endanger or impair enjoyment of the resource in an adjacent town.

Plan Element: Make increased use of regulatory measures and preservation techniques to ensure that development-sensitive areas are adequately protected.

Opportunities for Implementation: Soil mapping in Plymouth County has been completed and published. The Soil Survey Report for Plymouth County provides soil interpretations for various uses to guide planners in making sound land use decisions. Among other items, the Soil Survey indicates the location of wetlands, steep land, rocky land, and areas with a high water table. Soil limitations for septic tank fields, home sites, school sites, and athletic fields are presented. Technical assistance is available through the Raynham, Massachusetts, Field Office of the Soil Conservation Service, to interpret the Soil Survey Report.

Chapter 780 of the Acts of 1977, Massachusetts General Laws, administered by the Division of Conservation Services working in cooperation with local conservation commissions, authorizes the purchase of development rights to maintain land in farm use. The Act seeks to slow the loss of critical farmland by the purchase of development rights and the simultaneous provision of working capital to the selling farmer. Local cost sharing of the purchase cost normally results in higher priority access to the limited funds available from the state.

The Horticultural Land Assessment Act under Chapter 61A of the General Laws can be used to encourage the preservation of agricultural land use through reduced assessments and reduced local real estate taxes. The Forestland Assessment Act, Chapter 61 of the General Laws, might also be used to assist in the preservation of prime farmland soil in forestland use so that it will be available for conversion to farmland in the future.

The Federal Emergency Management Agency provides communities with the opportunity to participate in the National Flood Insurance Program. All eight of the basin towns are participating in the program. In return for federally subsidized insurance rates, the community must agree to consider flood hazards before approving development and to severely limit development in flood-prone areas. The towns are encouraged to continue participation in the program.

The Division of Conservation Services can assist towns to acquire conservation land through the Massachusetts Self-Help Program.

Chapter 4

ALTERNATIVES

This chapter presents an array of alternatives or components of a plan that could be utilized to meet the identified problems and concerns.

Each alternative describes an individual measure that a town could use to meet the need. A specific alternative could be combined with other alternative measures to achieve the desired result.

Alternatives described in this chapter are indicated below:

Water Supply Alternative - Water Conservation

The concept of water conservation is receiving increasing public interest as a means of reducing the need for development of additional water supplies. While water conservation will not result in any increased safe yield to a system it does offer the potential to reduce demand. In order to be successful, a conservation program requires a combination of mechanical devices, institutional arrangements, consumer education programs, and most importantly, positive co-operative attitudes on the part of water users.

Mechanical water-saving devices are usually intended to reduce water consumption without making the decreased water use noticeable to the user. Faucet aerators that mix air with the water stream are common water-saving devices that save water without interfering with function. Energy-saving "water-widgets" distributed by some energy utilities to cut down the consumption of hot water in showers decrease the quantity of water used. There are many other devices such as vacuum flush toilets, water saver toilets, flow-limiting valves, toilet tank inserts, and "instant" hot water heaters intended to decrease water consumption without affecting the standard of living.

Use of water-saving devices is mandated for new construction and renovating through the State Building Code, but existing facilities can normally only be converted to water-saving features if consumers can be convinced of the value. A public education campaign to change public attitudes toward municipal water supply is needed if conservation efforts are to be successful. Massachusetts residents have viewed municipal water as an inexpensive, boundless resource. Increasing demands for water have been met with increased municipal expenditures for the development of new sources. Water users will need to be told why water should now be conserved, what benefits will accrue to the user and the community, and what conservation techniques are available.

Most authorities agree that a successful water conservation program requires universal metering of water used so that all consumers pay for the water they use. In the North and South Rivers Basin the percentage of metered users is already very high.

Changes in the rates charged for water are usually included in water conservation plans. The common decreasing block rates under which large users pay less per unit of water than small users discourage conservation. Among the suggestions for rate changes to encourage conservation are increasing or uniform rates for all users, and surcharges on summer use to dissuade people from excess or unnecessary use of water during periods of peak demand.

The effect of water-saving devices depends on the number of users that install the devices. A good public information campaign could result in significant participation in the water conservation program. Likewise, "non-nessential" uses of water such as for car washing and lawn watering could be reduced if people were convinced of the need to reduce consumption during the summer periods of highest demand.

The Massachusetts Water Supply Policy Study presented some data on potential savings that might be achieved through water conservation measures. Table 4-1 indicates some of the measures and their effect as presented in the statewide report. Some of these measures would be expected to produce significantly different results in the North and South Basin communities because of the composition of water users. The Basin has a very small industrial component which limits the potential savings in that sector.

Table 4-1

Potential Savings in Selected Massachusetts Communities

With Specific Water Saving Devices 1/

	Item	Percentage Saving
1.	Water conservant toilets and showers for all new and replacement installations.*	4.2
2.	Installation of displacement devices in existing toilets.*	2.2
3.	Installation of flow control devices on sinks.*	1.2
4.	Modification of washing machines.**	0.3
5.	Modification of dishwashing procedures.**	0.6
6.	Elimination of food disposers.**	1.2
7.	Modification of commercial and home car washing procedures.*	0.4
8.	Meter all existing flat rate users.*	1.5
9.	Replacement of commercial and industrial flush-type toilets.**	0.2
10.	Replacement of grass areas with mulch.**	1.0
11.	Industrial Reuse.*	3.5
	Total	16.3

1/ After Table 6-12 "Massachusetts Water Supply Policy Study," Massachusetts Executive Office of Environmental Affairs, January 1977.

* Relatively easy to achieve

** Relatively difficult to achieve

Reuse of "gray water" (from sinks, tubs, and other non-toilet sources) has also been receiving increased attention as a source of water for toilet flushing, yard watering, and other uses where potable water is not required.

Costs of implementing specific water-saving measures in a particular community are difficult to assess because of the lack of adequate data to define the presence of existing conservation measures in the town and the lack of studies indicating the degree of participation in conservation among water users. However, some general observations concerning costs will be helpful in assessing the cost of conservation measures as compared with the cost of more conventional supply-increasing measures.

Table 4-1b

Cost of Water Conservation Measures

Measure	Cost Observations
1. Water conservant toilets and showers for all new and replacement installations.	Studies by the Old Colony Planning Council indicate that water conserving fixtures are normally within $5.00 of the cost of ordinary fixtures.
2. Installation of displacement devices in existing toilets.	Cost can range from zero for plastic jugs filled with water to $10.00 for manufactured devices.
3. Flow control devices on sinks.	$0.10 to $2.00 if installed by water user.
4. Modification of washing machines.	Cost could run over $100.00 per machine for installed devices.
5. Modification of dishwashing procedures.	Little or no cost involved; procedural changes required.
6. Elimination of food disposers.	Direct costs would be minimal but increased solid waste collection and disposal costs may result.
7. Modification of commercial and home car washing procedures.	Home washing procedures involve use of water only when necessary for wetting and rinsing--no cost to implement. Commercial procedures could involve recirculating water and cost in the range of $15,000-$30,000.
8. Meter all existing flat rate users.	Over 95% of the users in the Basin are metered. Four towns have 100% metering. Cost to meter the 700 unmetered services estimated to be $140,000.
9. Replacement of commercial and industrial flush-type toilets.	Estimated at $300.00 per toilet. Number of commercial and industrial toilets in the Basin is not known.
10. Replacement of grass areas with mulch.	Estimated at $2,000.00 per acre of area converted to mulch. No estimate of area to be converted is available.
11. Industrial reuse.	Industrial use within the Basin is minimal.
12. Reuse of domestic "gray water."	Retrofitting of an existing home could easily exceed $2,000.00 because of the need to install separate drainage systems, a separate gray water distribution system, storage facilities, and a pump to provide pressure to circulate the gray water. Costs to install a system in new construction would be less.

An effective water conservation program also requires a consumer education component to foster a positive cooperative attitude on the part of water users. The education program needs to be a continuing effort to ensure that water conservation is kept in the thoughts of consumers. Other towns have tried various methods including reminders sent with utility bills; school programs involving a conservation unit in the curriculum; radio, television, and newspaper reminders; and special efforts at the beginning of the car-washing and swimming pool filling seasons.

If the basin towns are serious about establishing an effective water conservation program, it will be necessary to adequately fund the effort. Sufficient financing needs to be available to support printing, advertising, and most important, personnel with time and interest to devote to the encouragement of water conservation. Basin towns could cooperate in the funding of a water conservation coordinator to serve all eight communities and develop an integrated conservation effort. The needs of each town are essentially similar and there could be monetary savings and operational efficiencies through a shared coordinator. Annual cost of developing and implementing a consumer education program is estimated at $25,000.

With the small industrial demand for water in the North and South Rivers Basin and the relative difficulty of achieving some of the potential savings in Table 4-1, it is realistic to assume that water conservation measures in the basin towns might result in savings in the range of 8-10 percent of per capita demand.

Historically, per capita demand for water has been increasing. This increase has been attributed to an increasing standard of living and the increasing acquisition of water-using appliances such as washing machines, diswashers, and garbage disposals. The rate of per capita increase varies between communities but the Water Supply Policy Study suggests that a yearly increase of 1.1 gallons per day is consistent with American Water Works Association standards. The Massachusetts Division of Water Resources estimates that per capita demand will increase about one percent per year in the absence of conservation measures.

Table 4-2 indicates the effect of a yearly one percent per capita demand increase in the North and South Rivers Basin communities.

Table 4-2

Daily Per Capita Demand With One Percent Per Year Increases

Town	Present Per-Capita Demand 1/	Gallons Per Capita Per Day		
		Future Year		
		1990	2000	2020
Duxbury	105	115	126	153
Hanover	96	107	118	140
Hanson	66	77	88	110
Marshfield	122	134	147	178
Norwell	115	124	137	165
Pembroke	62	68	83	91
Rockland	86	95	105	127
Scituate	104	114	125	152

1/ Per capita demand computed as average daily demand divided by permanent population. Based on 1980 and 1981 available data, the large range in per capita demand is primarily due to seasonal increases in population which distort average demand figures in towns with a large influx of summer residents.

Table 4-3 presents a summary of per capita demand that could result if conservation measures were successful in decreasing consumption by various percentages.

Comparison of the per capita demand rates in Table 4-2 with those in Table 4-3 indicates that substantial decreases in expected demand might be achieved through conservation. For instance in Marshfield the per capita demand is expected to be about 134 gallons per day by 1990. If conservation efforts could produce a 10 percent reduction in present day consumption and maintain consumption at that rate into the future, only 110 gallons per day would be needed per person, the savings seem more significant when multiplied by the 1990 permanent service population of 25,760 yielding a reduction in maximum daily demand of over 540,000 gallons. This is about equivalent to the yield from a municipal well of the type comprising the Marshfield system.

Table 4-3

Per Capita Demand with Various Percent Reductions

Town	Present Demand	Demand in Gallons Per Person Per Day				
		Demand Reduction Percentage				
		10%	15%*	20%*	30%*	40%*
Duxbury	105	95	89	84	74	63
Hanover	96	86	82	77	67	58
Hanson	66	59	56	53	46	40
Marshfield	122	110	104	98	85	73
Norwell	115	104	98	92	81	69
Pembroke	62	56	53	50	43	37
Rockland	86	77	73	69	60	52
Scituate	104	94	88	83	73	62

*Demand Reduction Percentages above 10 percent are presented for illustrative purposes only. An effective water conservation program in the Basin would be likely to achieve reductions in the range of 8-10 percent.

Table 4-4 indicates the unmet need (demand minus the capacity of the developed resources to meet demand) resulting from a range of conservation assumptions for various projection years in the planning time frame. The data in the table indicate that many of the basin communities could significantly reduce intermediate term needs through conservation.

Table 4-5 presents a summary of the water conservation measures presently being undertaken in the North and South Rivers Basin.

Table 4-4

Projected Unmet Municipal Water Supply Needs Under a Range of Conservation Assumptions

	PROJECTION YEAR											
	1990				2000				2020			
Town	Population	With Projected Increasing Per Capita Demand	With Constant Per Capita Demand	With 10% Reduction in Present Per Capita Demand	Population	With Projected Increasing Per Capita Demand	With Constant Per Capita Demand	With 10% Reduction in Present Per Capita Demand	Population	With Projected Increasing Per Capita Demand	With Constant Per Capita Demand	With 10% Reduction in Present Per Capita Demand
					(Millon Gallons Per Day)							
Duxbury	14,400	1.3	0.9	0.5	14,600	1.8	1.0	0.6	15,500	3.1	1.2	0.8
Hanover	12,900	surplus	surplus	surplus	13,200	surplus	surplus	surplus	13,300	0.5	surplus	surplus
Hanson	10,400	surplus	surplus	surplus	10,600	surplus	surplus	surplus	10,700	surplus	surplus	surplus
Marshfield	23,700	1.6	1.1	0.6	24,300	2.4	1.2	0.7	24,500	3.9	1.3	0.7
Norwell	11,100	0.3	0.2	surplus	11,600	0.6	0.2	surplus	11,700	1.2	0.2	surplus
Pembroke	16,500	0.6	0.4	0.2	17,200	1.0	0.5	0.3	17,500	1.7	0.6	0.3
Rockland	15,700	1.7	1.3	0.9	15,700	2.2	1.4	1.0	15,700	3.6	1.7	1.2
Scituate	17,300	1.0	0.8	0.5	17,300	1.4	0.8	0.5	17,300	2.2	0.8	0.5

Projected unmet needs assume that no additional sources are developed to supplement existing supplies.

Table 4-5

Summary of Water Conservation Measures

North-South Rivers Basin

Town	Metering of Use (%)	Rate Structure	Leak Detection Studies	Preventive Maintenance	Encouragement of Water Saving Devices	Ban of Non-essential Uses	Water Conservation Education
Duxbury	100	Block Rate	x	x			
Hanover	100	Increasing Block Rate	x	x	x	Used in Past	x
Hanson	97	Decreasing 2 Block Rate		x	x		x
Marshfield 1/							
Norwell	95	Block Rate				When Necessary	
Pembroke	100	Decreasing Block Rate					
Rockland	100	Block Rate	x	x	x	When Necessary	x
Scituate	95	Block Rate	x	x			

1/ Information unavailable for Marshfield.

Water Supply Alternative - Potential Surface Water Reservoir Sites

In 1975, the Soil Conservation Service published an "Inventory of Potential and Existing Upstream Reservoir Sites--South Shore, Cape Cod, Buzzards Bay & Islands Study Areas" encompassing the North and South Rivers Basin. The inventory presented basic data for about 20 potential reservoir sites in the Basin. Many of the sites are not suitable for the permanent storage of water because of adverse geologic conditions--primarily the presence of deep, permeable sand and gravel deposits in the abutments and foundations of the sites. However, five of the sites identified appear to warrant further investigation as potential municipal water supply reservoirs.

Data relating to the five sites are presented in Table 4-6. The data are based on preliminary information obtained in 1975 as a result of reconnaisance visits to each site and surficial geologic investigations. Detailed studies including drilling of test holes, detailed geologic testing, engineering and hydrologic studies, and property value estimates need to be made before an accurate determination can be made as to the usefulness of a particular site to meet a town's needs. The limited data now available on these potential reservoir sites can serve to direct attention to possibilities for additional water supply that may not have been considered previously.

Also included in Table 4-6 are data for two additional surface water reservoir sites that have been identified in other studies.

If the reservoir sites identified in Table 4-6 were developed for use by the towns in which they are located, the effect upon future needs for additional water supply would be as indicated in Table 4-7.

Towns that rely entirely upon groundwater must be designed so that the safe yield of the wells will meet the maximum daily demands of the town. Systems that utilize surface water reservoirs or a combination of surface and groundwater can respond to short-term increases in demand by drawing upon stored surface reserves to meet temporary surges. Design of systems employing surface sources that do not require processing through a treatment plant, can usually be based upon meeting average daily demand that ranges from one-half to one-third of the maximum daily demand. Thus, Table 4-7 compares the system safe yield to projected average daily demand rather than maximum demand to determine need for additional supplies.

Table 4-6. Potential Surface Water Reservoir Site Data

Site	Location	Drainage Area (Sq. Mi.)	Maximum Depth (Ft.)	Maximum Storage (MG)	Safe Yield (MGD)	Remarks
SS-2703	Norwell	1.6	16	300	0.9	Located on First Herring Brook at the Scituate-Norwell town line in Norwell. Both abutments are poorly graded sand and gravel with cobbles and boulders. Seepage through abutments may be a problem. Located downstream of South Swamp--may have water quality problems. Total cost estimated to be $3,050,000.
SS-2705	Norwell	0.9	14	105	0.3	Located north of Norwell Ave. in Norwell. Both abutments are poorly graded coarse sand and gravel. Seepage through abutments may be a problem. Right abutment is covered with boulders. Located downstream from Black Pond Swamp--may have water quality problems. Total cost estimated to be $1,900,000.
SS-2712	Marshfield	0.9	36	229	0.6	Located on Cove Brook south of Highland St. in Marshfield. Left abutment is poorly graded sand and gravel. Seepage through abutment may be a problem. Total cost estimated to be $2,450,000.
SS-2716	Pembroke	3.6	17	622	1.9	Located on Pudding Brook west of Pleasant St. in Pembroke. Both abutments are poorly graded sand and gravel outwash. Seepage through both abutments may be a problem. The site is now a cranberry bog reservoir. Total cost estimated to be $3,350,000.
SS-2801	Marshfield	0.9	27	144	0.4	Located on Hannah Eames Brook west of Summer St. in Marshfield. Abutments are glacial till. Water holding capabilities should be good. Total cost estimated to be $1,850,000.
Hanover	Hanover	8.0	25	279	1.3	Located on a tributary to Third Herring Brook northeast of Old Washington St. in Hanover. Diversion of flow from Third Herring Brook would be required. Safe yield based on diversion of one-half of all flows in Third Herring Brook. Total cost estimated to be $6,750,000.
Scituate	Scituate	1.8	20	542	1.2	Located on First Herring Brook south of Parish Rd. and west of Grove St. in Scituate. Pool area would extend into Norwell. This site is located about 1/2 mile downstream from Site SS-2703. Total cost estimated to be $5,100,000.

MG = Million Gallons
MGD = Million Gallons per Day

Table 4-7. Projected Municipal Water Supply Needs with Surface Reservoir Sites. (Millions of Gallons per Day)

Town & Reservoir Site	Safe Yield of Site (MGD)	PROJECTION YEAR 1990 Need Without Reservoir	1990 Need With Reservoir	2000 Need Without Reservoir	2000 Need With Reservoir	2010 Need Without Reservoir	2010 Need With Reservoir	2020 Need Without Reservoir	2020 Need With Reservoir
Hanover Hanover Site	1.3	Surplus	Surplus	Surplus	Surplus	0.2	Surplus	0.5	Surplus
Marshfield Site SS-2712	0.6	1.6	1.0	2.4	1.8	3.1	2.5	3.9	3.3
Marshfield Site SS-2801	0.4	1.6	1.2	2.4	2.0	3.1	2.7	3.9	3.5
Marshfield Site SS-2712 & Site SS-2801	1.0	1.6	0.6	2.4	1.4	3.1	2.1	3.9	2.9
Norwell 1/ Site SS-2703	0.9	Surplus	Surplus	0.6	Surplus	0.9	Surplus	1.2	0.3
Norwell Site SS-2705	0.3	Surplus	Surplus	0.6	0.3	0.9	0.6	1.2	0.9
Norwell Site SS-2703 & SS-2705 1/	1.2	Surplus	Surplus	0.6	Surplus	0.9	Surplus	1.2	Surplus
Pembroke Site SS-2716	1.9	0.6	Surplus	1.0	Surplus	1.3	Surplus	1.7	Surplus
Scituate Scituate Site 1/	1.2	1.0	Surplus	1.4	0.2	1.8	0.6	2.2	1.0

1/ Site SS-2703 and the "Scituate" Site share a portion of pool area. Only one of the sites can be utilized.

Water Supply Alternative - Previously Identified Groundwater Options

Communities in the North and South Rivers Basin have engaged a number of consultants to evaluate groundwater resources and recommend possible alternatives to meet water supply needs. Previously identified alternatives are summarized in this section.

The cost of developing a well for municipal production and connecting the well to the existing distribution system includes many items such as drilling cost, well casing and screen, test pumping and well development, pump house, pump and motor, pump controls, recording equipment, telemetry apparatus, land rights, and pipe and valves necessary to connect to the system. Some of the costs are site-dependent but the majority of the identified groundwater options could be brought into production for about $500,000 each.

Duxbury

Whitman and Howard, Consulting Engineers, conducted an exploratory drilling program to locate additional sources of groundwater. Several areas were suggested for further exploration and development and are summarized in Table 4-8.

Table 4-8

Whitman & Howard Recommendations

Site Number	Prolonged Pump Test Conducted	Town-Owned Land	Estimated Safe Yield (gpm)	Quantity That Could Be Pumped in 16 Hours (gallons)
110	x	x	450	432,000
40	x	x	300	288,000
106	x		300	288,000
2	x	x	300	288,000
112		x	450	432,000
35		x	400	384,000
37		x	350	336,000
43		x	375	360,000

Hanover

Pump capacity installed in Hanover's wells ranges from 50 to 80 percent of the safe yield of the wells. It may be feasible to increase pump capacity to match safe yield more closely in order to raise the operating yield of the system. The town has found, however, that color, iron, and manganese levels increase as the wells are pumped closer to their safe yield. If pump capacity matched well safe yield, 4.2 million gallons could be obtained with a 16 hour per day pumping cycle.

Water from the three Pond Street wells is pumped through a treatment plant with a capacity of 2.0 million gallons per day. Unless treatment plant capacity were increased, safe yield of the system would be limited to 3.3 MGD with all pumps matched to the safe yield of the wells.

Hanson

The Old Colony Planning Council's Groundwater Resources Study suggested that significant amounts of sand and gravel may occur beneath portions of Great Cedar Swamp and in the Monponsett section of town indicating good potential for additional well sites.

Marshfield

A Groundwater Resource Inventory prepared by Goldberg-Zoino-Dunnicliff & Associates identified areas in Marshfield that merit further exploration as municipal groundwater sources. These aquifer areas are summarized in Table 4-9.

Table 4-9

Goldberg-Zoino-Dunnicliff Potential Exploration Areas

Area	Estimated Potential Yield
Furnace Brook Aquifer southwest of Furnace Pond	0.7 MGD*
Littles Creek Aquifer - southern part	0.8 MGD
Fairgrounds Basin Aquifer - northern area near Littles Creek Aquifer	0.8 MGD
South Marshfield Aquifer - east of Hall's Pond esker	Thought to be highly favorable
South Marshfield Aquifer - west of Black Mountain	Highly favorable

*May reduce or eliminate Furnace Brook flow during summer

Pembroke

A Groundwater Resources Study prepared by the Old Colony Planning Council included the town of Pembroke. The report identifies the aquifer in the southern half of Pembroke as the most sizable and thickest in the area, with many communities using water from the aquifer. Future groundwater explorations were directed to this area.

Rockland

A study in 1953 by Weston and Sampson, Consulting Engineers, resulted in an exploration program and the drilling of 86 test wells. Subsequently, the Abington-Rockland Joint Water Board identified the Meyers Avenue area and the vicinity of Great Sandy Bottom Pond in Pembroke as the most promising sites for future groundwater development.

Scituate

Seismic studies by Weston Geophysical Engineers recommended three areas for further groundwater exploration:

a. East of Brushy Hill between Stockbridge and First Parish Roads.

b. Satsuit Meadow adjacent to Norwell.

c. The South Swamp-Cedar Street-Clapp Road area in the northwest corner of town.

Areas a. and c. have been eliminated from consideration by the town. Testing on Area b. has shown poor results.

In addition, a town water resources study committee suggested recharge of the Well Number 18 aquifer using water that is currently spilled from Old Oaken Bucket Pond; utilizing the abandoned Well Number 21 by pumping through the water treatment plant; and restoration of the Kent Street and Beaver Dam well fields. The town presently considers restoration of the Beaver Dam well field to be uneconomical because of low volume.

Water Supply Alternative - Combinations to Meet Identified Needs

Information has been presented on alternatives to meet identified needs through water conservation, surface water reservoirs, and previously identified groundwater options.

Many combinations of alternatives can be proposed to satisfy projected needs. The choice of a plan is a decision usually based on local priorities and preferences.

An array of possible combinations is presented below to illustrate how the water supply needs might be met with a variety of the previously discussed alternatives. Because of state and local interest in incorporating water conservation measures in water supply planning, an alternative utilizing only conservation measures is presented for each town. It is noted that reductions in demand of over 10 percent will be difficult to achieve.

DUXBURY

Examples of measures to meet projected 1.8 million gallons per day (MGD) need in the year 2000.

Measures	Contribution to meeting unmet need (MGD)
Conservation measures to reduce per capita demand by about 24% (Difficult to achieve)	1.8
Conservation measures to reduce per capita demand by about 14% (Difficult to achieve)	1.4
Development of a well (site 110 or 112)	0.4
	1.8
Conservation measures to reduce per capita demand by about 7%	1.1
Development of two wells (site 110 & 40)	0.7
	1.8
Development of five wells (sites 110, 40, 106, 2 & 112)	1.7

Examples of measures to meet projected 3.1 million gallons per day (MGD) need in the year 2020.

Measures	Contribution to meeting unmet need (MGD)
Conservation measures to reduce per capita demand by about 24% (Difficult to achieve)	3.1
Conservation measures to reduce per capita demand by about 19% (Difficult to achieve)	2.7
Development of a well (site 110 or 112)	0.4
	3.1
Conservation measures to reduce per capita demand by about 12% (Difficult to achieve)	2.4
Development of two wells (site 110 & 40)	0.7
	3.1
Development of eight wells	2.8

HANOVER

Examples of measures to meet projected 0.5 million gallons per day (MGD) need in the year 2020.

Measures	Contribution to meeting unmet need (MGD)
Conservation measures to maintain per capita demand at 1980 level	1.2
Surface reservoir site located on tributary to Third Herring Brook	1.3

HANSON

Hanson is projected to have adequate supplies to meet demand through 2020 with two new wells to be brought into the system in October 1982 and continuing supplies from the Brockton Water Commission.

MARSHFIELD

Examples of measures to meet projected 2.4 million gallons per day (MGD) need in the year 2000.

Measures	Contribution to meeting unmet need (MGD)
Conservation measures to reduce per capita demand by about 22% (Difficult to achieve)	2.4
Conservation measures to reduce per capita demand by about 7%	1.6
Develop one well	0.8
	2.4
Conservation measures to maintain per capita demand at 1980 levels	1.9
Develop two wells	1.6
	3.5
Develop two surface reservoirs	1.0
Conservation measures to reduce per capita demand by about 4%	1.4
	2.4
Develop two surface reservoirs	1.0
Develop one well	0.8
	1.8
Develop one surface reservoir	0.4
Develop two wells	1.6
Conservation measures to maintain per capita demand at 1980 levels	1.9
	3.9
Develop three wells	2.3

MARSHFIELD

Examples of measures to meet projected 3.9 million gallons per day (MGD) need in the year 2020.

Measures	Contribution to meeting unmet need (MGD)
Conservation measures to reduce per capita demand by about 22% (Difficult to achieve)	3.9
Develop two wells	1.6
Conservation measures to maintain per capita demand at 1980 levels	2.6
	4.2
Develop three wells	2.3
Conservation measures to maintain per capita demand at 1980 levels	2.6
	4.9
Develop two surface reservoirs	1.0
Conservation measures to reduce per capita demand by about 8%	2.9
	3.9
Develop two surface reservoirs	1.0
Develop three wells	2.3
	3.3

NORWELL

Examples of measures to meet projected 0.6 million gallons per day MGD) need in the year 2000.

Measures	Contribution to meeting unmet need (MGD)
Conservation measures to reduce per capita demand by about 8%	0.60
Conservation measures to maintain per capita demand at 1982 level.	0.43
Develop surface reservoir (site SS-2705)	0.30
	0.73
Develop surface reservoir (site SS-2703)	0.9

NORWELL

Examples of measures to meet projected 1.2 million gallons per day (MGD) need in the year 2020.

Measures	Contribution to meeting unmet need
Conservation measures to reduce per capita demand by about 9 percent	1.2
Conservation measures to maintain per capita demand at 1982 level	0.9
Develop surface reservoir (site 2705)	0.3
	1.2

PEMBROKE

Examples of measures to meet projected 1.0 million gallons per day (MGD) need in the year 2000.

Measures	Contribution to meeting unmet need
Conservation measures to reduce per capita demand by about 23% (Difficult to achieve)	1.0
Develop surface reservoir (site 2716)	1.9
Develop two wells (location undetermined)	1.0

PEMBROKE

Examples of measures to meet projected 1.7 million gallons per day (MGD) need in the year 2020.

Measures	Contribution to meeting unmet need
Conservation measures to reduce per capita demand by about 24% (Difficult to achieve)	1.7
Develop surface reservoir (site 2716)	1.9
Develop one well (location undetermined)	0.5
Conservation measures to reduce per capita demand by about 2%	1.2
	1.7

ROCKLAND

Examples of measures to meet projected 2.2 million gallons per day (MGD) need in the year 2000.

Measures	Contribution to meeting unmet need
Conservation measures to reduce per capita demand by 31% (Difficult to achieve)	2.2
Expand Hingham St. Reservoir	0.5
Conservation measures to reduce per capita demand by 16% (Difficult to achieve)	1.7
	2.2

ROCKLAND

Examples of measures to meet projected 3.6 million gallons per day (MGD) need in the year 2020.

Measures	Contribution to meeting unmet need
Conservation measures to reduce per capita demand by about 36% (Difficult to achieve)	3.6
Expand Hingham St. Reservoir	0.5
Conservation measures to reduce per capita demand by about 22% (Difficult to achieve)	3.1
	3.6

SCITUATE

Examples of measures to meet projected 1.4 million gallons per day (MGD) need in the year 2000.

Measures	Contribution to meeting unmet need
Conservation measures to reduce per capita demand by about 25% (Difficult to achieve)	1.4
Develop surface reservoir (First Herring Brook)	1.2
Conservation measures to maintain per capita demand at 1980 level	0.6
	1.8

Examples of measures to meet projected 2.2 million gallons per day (MGD) need in the year 2020.

Measures	Contribution to meeting unmet need
Conservation measures to reduce per capita demand by about 25% (Difficult to achieve)	2.2
Develop surface reservoir (First Herring Brook)	1.2
Conservation measures to maintain per capita demand at 1980 level	1.4
	2.6
Develop new well	0.2
Conservation measures to reduce per capita demand about 18% (Difficult to achieve)	2.0
	2.2
Develop new well	0.2
Utilize well #21 (Wagner's Meadow)	0.4
Conservation measures to reduce per capita demand by about 5%	1.6
	2.2

Water Supply Alternative - Geohydrologic Studies

Geohydrologic studies are made to systematically develop a resource data base to identify potential groundwater sites for municipal development.

Table 4-10 indicates some of the steps involved in performing a geohydrologic study.

Communities in the North and South Rivers Basin have expended a great deal of effort in the past to locate geologically favorable sites for groundwater development; some or nearly all of the steps outlined in Table 4-10 have been completed. A prudent action would be to complete the missing steps in each community to have a complete inventory of the resource.

Table 4-10

Geohydrologic Methodology for Groundwater Exploration

A. Assemble available geohydrologic data from consultants, drilling contractors, state and federal agencies, and town officials.

B. Screen data for accuracy.

C. Transfer data to a common base and produce maps:

   1. Surficial materials map
   2. Groundwater contour map
   3. Saturated thickness map; depth to bedrock map
   4. Transmissivity map

D. Analyze maps for completeness.

E. Make field reconnaissance to judge adequacy of available data.

F. Evaluate surficial geologic characteristics.

G. Determine areas needing additional subsurface geologic investigation.

H. Set priorities and plan detailed investigation.

I. Perform detailed geologic investigation:

   1. Evaluate surficial materials map and analyze seismic data
   2. Drill at best locations
   3. Evaluate data as drilling progresses
   4. Perform 2" pump tests on "good" sites
   5. Prepare geologic cross sections on aquifers based on all test drilling

J. Perform 8" pump test 7 days on best locations, monitored by hydrogeologist.

K. Develop well.

Duxbury

A townwide geohydrologic study should be undertaken to gather and review geologic data. Such a study will provide analysis of identified and potential well sites and assemble a data base needed for a groundwater protection program. This will enable the town to evaluate potential sites before development makes them unavailable.

Whitman and Howard (1979) have determined the geologically favorable locations in town for further exploration. The town needs to have these locations incorporated into a townwide study to determine subsurface geologic relationships.

Hanover

Hanover and Norwell should engage in a cooperative groundwater study. Approximately 80 percent of the water contributed to Hanover's Pond Street wells is from upgradient areas in Norwell. Activities in Norwell can have a detrimental effect on Hanover's water supply, as well as Norwell's.

Hanson

The town should investigate the highly transmissive portions of the southwest regional aquifer system identified in the Old Colony Planning Council Groundwater Resources Study following the Geohydrologic Methodology from Step D in Table 4-10.

The town should also investigate cooperative management with other communities of ground and surface water in the regional aquifer system. This would improve management of a resource now being shared by Pembroke, Hanson, Brockton, Whitman, Rockland, and Abington.

Norwell

A complete geohydrologic study should be completed to identify and quantify groundwater resources in the town. This will ensure a data base from which to proceed with protection by-laws in the zoning code. Hanover and Norwell should engage in a cooperative groundwater study. Approximately 80 percent of the water contributed to Hanover's Pond St. wells is from upgradient areas in Norwell. Groundwater hazards in Norwell can have a detrimental effect on Hanover as well as Norwell.

Pembroke

Investigate the most highly transmissive portions of the southwest regional aquifer system identified in the Old Colony Planning Council Groundwater Resources Study following the Geohydrologic Methodology from Step D forward in Table 4-10.

Investigate conjunctive management of ground and surface water in the regional aquifer system. This would allow management of a resource now being shared by Pembroke, Brockton, Whitman, Rockland, and Abington.

Rockland

Procedures outlined in the Geohydrologic Methodology for Groundwater Exploration will provide a data base for identifying additional well sites.

Scituate

The town has vigorously explored for groundwater since 1930. The 1975 report by the town committee indicates the town has been thoroughly explored for water. Weston Geophysical was hired in 1977 to perform seismic refraction studies to find suitable areas to drill for water. Areas recommended to be drilled have been investigated.

Before abandoning groundwater to fulfill additional needs, a complete geohydrologic study should be done as outlined in Table 4-10. Only after a thorough examination should groundwater be excluded as an alternative.

Where suitable, different types of wells may meet the needs of Scituate. A well field similar to the abandoned Beaverdam Well group can be installed where saturated shallow sands and gravels occur. Well point systems offer the advantage of being able to pump from large storage in shallower saturated areas than those required for large diameter gravel packed wells.

Webster's Meadow Wells 10 and 11 have recently been overhauled, but the possibility of larger capacity wells in the same area could be investigated to take full advantage of a large saturated thickness of sand and gravel. This investigation could be done as part of a complete geohydrologic compilation.

Water Quality Alternative -Aquifer Protection

Five towns in the North and South Rivers Basin have some form of aquifer protection. Scituate formerly had a program to purchase land near well fields. Norwell has "no salt" zones posted in the vicinity of wells. Hanover has proceeded the furthest toward a groundwater protection bylaw. Recent long-term pump tests will provide radii of the cones of depression for incorporation into an aquifer protection bylaw. Marshfield has inventoried groundwater resources, but has not provided for protection of groundwater. Duxbury has an ongoing program to buy conservation land around its wells. Pembroke, Hanson, and Rockland have no formal groundwater protection programs. In 1981, the Hanover town meeting passed an aquifer protection zoning bylaw only to have town meeting action invalidated over a procedural question.

Comprehensive aquifer protection begins with a geohydrologic study of the groundwater resources of the area to define the extent and potential of aquifers and to identify significant recharge areas. After the aquifers and recharge areas are determined, towns can begin to prepare specific protection guidelines and protective bylaws. Steps that can be taken by individual communities are presented below.

Duxbury

Duxbury has taken steps to protect groundwater. "No salt" zones have been established near the wells, and conservation land has been purchased around wells. The following items are recommended:

1. Several underground gas storage tanks are near well watersheds. (See Figure IV-4, Potential Groundwater Hazard Map.) The tanks should be monitored and replaced if necessary.

2. In order to gain maximum benefit from future purchases of conservation land for groundwater protection, well testing should be performed. Pumping tests should be done to determine pumping cones of depression so that these areas can be recommended for local purchase. Ultimately, the town should have a study done to determine the aquifer boundaries.

3. The salt shed located near wells T1 and T2 should be managed to reduce salt runoff from the shed and surrounding area to a minimum.

Hanover

SEA Consultants, Inc., in cooperation with Goldberg-Zoino, Inc., prepared a report on Protection of Groundwater Supply for the town in 1979. The following recommendations are quoted from that report:

"1. An aquifer protection district bylaw should be drafted.

"2. Because the water quality in the Pond Street well field can be affected by water quality in Third Herring Brook, a watershed protection plan for the brook should be established. This will require the involvement and cooperation of the town of Norwell.

"3. The stream entering the Pond Street well field south of Mill Street should be diverted to Third Herring Brook by a storm drain which includes oil and sediment traps.

"4. The amount of sodium chloride used for deicing in the aquifer protection district by the state and town Department of Public Works should be monitored and recorded. Average application rate should not exceed 7.4 tons per land mile per year.

"5. Petroleum storage tanks in the aquifer protection district should be pressure tested periodically to detect leaks.

"6. A survey should be made of all businesses in the aquifer protection district to determine if toxic chemicals are being discharged.

"7. A contingency plan should be developed to respond to spillage of liquid cargoes.

"8. Monitoring wells should be constructed. Groundwater and streams should be sampled and tested in a regular program to compile baseline water quality data and detect contamination before it reaches the water supply well.

"9. The use of sodium hydroxide for corrosion control in the water distribution system should be discontinued. Replacement with alternative chemicals such as lime should be studied and implemented.

"10. The town should consider the option of purchasing all land within the 7-day cones of influence of all wells.

"11. Additional field testing should be carried out to clearly identify the limits of the 7-day cones of influence of all wells. This data is necessary to support the criteria being proposed in the aquifer protection district by-law.

"12. Additional studies should be carried out to more clearly establish the boundaries for the Hanover Street and Broadway well fields.

"13. Additional testing and analysis for toxic chemicals should be made at all existing wells."

Hanson

1. A "no salt" zone should be established along Franklin Street from Washington to Main.

2. A geohydrologic study of potential landfill effects on the new well site should be undertaken, unless already done.

3. Periodically pressure test petroleum storage tanks located in primary aquifer areas.

4. Pass groundwater protection bylaws in the aquifer area for quality and recharge protection.

5. Where land surrounding the well is zoned industrial, special care must be taken to protect groundwater. Industrial land use offers potential hazards to groundwater resources. If possible, regulations should be developed within a groundwater protection bylaw to require consideration of groundwater resources. Should regulatory means not prove to be a possible alternative, the town should change the industrial district where it can be shown that these areas contribute to recharge of the well.

Norwell

Recommendations from the IEP Study are presented below.

1. A joint water resource groundwater protection program should be pursued by Norwell and Hanover. Eighty percent of water contributed to Hanover's wells is from upgradient areas in Norwell. Hanover is dependent upon Norwell for the protection of this supply.

2. Hanover and Norwell should address themselves to protecting Third Herring Brook, Jacobs Pond tributaries, and their associated wetlands which contribute to water supply of both towns.

3. Protect all recharge areas and aquifers.

4. Identify all commercial industrial areas where large volume wastewater disposal is required.

5. Limit roadway salting areas; especially Route 3 where it crosses the Old Pond Meadows areas.

IEP urged the adoption of a groundwater protection district which is an overlay district superimposed on all underlying districts.

Road salting should be reduced to amounts quoted in the SEA Consultants' report for Hanover. Average application of 7.4 tons per lane mile per year in Hanover was judged adequate.

Petroleum storage tanks in town, particularly those located in well watersheds, should be pressure tested periodically and checked for leaks.

All existing wells should be completely tested for toxic chemicals.

Pembroke

The wells of Pembroke are located in a regional aquifer as identified by Goldberg-Zoino in the Old Colony Planning Council report. Groundwater protection should ideally be provided for this entire aquifer system. Geohydrologic boundaries have not been accurately defined by field work. Therefore, the following recommendations, while not supported by field testing, will provide some protection until such time as detailed studies are made.

1. Use of sodium chloride on roads for de-icing should be reduced on a town-wide basis to the absolute minimum for safety. Only the most hazardous areas should be salted to "clear pavement" conditions. Dumping of salt-laden snow should be done in an area removed from well recharge areas.

   To institute such regulations, DPW employees should be made aware of the potential pollution by salt in yearly pre-salting season meetings.

2. All gasoline or hazardous liquid storage areas in the town should be located and inspected for leaks. Should leaks be detected, tanks should be replaced.

After detailed geohydrologic studies of the regional aquifer system are performed, specific protection guidelines can be drafted and protective bylaws proposed. Some specific recommendations to protect groundwater quality are available now.

1. Wells 1, 2 and 3 are located in close proximity to highways. A "no salt" zone should be established on these highways. Highway salting should not be allowed from the intersection of Center and School Street east to Monroe Street, north on Monroe Street to where Center Street and Mountain Avenue intersect. The zone should then extend south from the intersection of Center Street and Monroe Street to the intersection of Main and Center.

2. Access to all wells should be restricted by suitable sturdy gates and/or fencing. Current easy access invites vandalism and potential pollution of the wells.

3. Well #3 is close to School Street (Route 27). Presently drainage patterns on this road may channel road run-off toward the well. To prevent this, roadside gutters should be built to divert this flow away from the well.

4. All potential entrances to the large abandoned sand and gravel pits southwest of Wells 2 and 3 should be blocked. This would make it difficult to dump potentially hazardous substances.

5. The sanitary landfill should be monitored for pollutant loading. In addition, a complete program of testing groundwater from wells should be undertaken. This landfill poses a potential hazard to Well #1.

Scituate

"No salt" zones should be instituted near all wells. In particular, Rte. 34 from Mann Lot Road to Greenbush should not be salted. Wells #10 and #11 can be protected from road salt with a "no salt" zone from Greenbush to Stony Brook along Rte. 23. Similarly, a "no salt" district in the subdivision west of Well #20 should be posted. Dumping of salt-laden snow should not be done near wells. The town has requested the state DPW to establish a "no salt" zone on Route 3A, but to no avail.

Underground gasoline storage tanks should be pressure tested and replaced, if necessary.

Use of sewers or one-acre zoning should be considered in any of the high density residential zones overlying recharge areas of wells.

Water Quality Alternative - Iron and Manganese Control

Natural compounds in groundwater are derived from the soil or rock with which the water is in contact. When natural compounds are excessively concentrated, the groundwater becomes less useful for drinking and other purposes. Iron sulfide compounds and manganese are common in the glacial soils of the North and South Rivers Basin. It is very difficult to predict where excessive iron and manganese will occur in an aquifer. Several wells drilled in the eight towns have shown excessive levels of iron and manganese. Generally, with prolonged pumping of a well, the problem accelerates and eventually the well must be abandoned.

Wells have been abandoned in Scituate and Rockland due to the high levels of iron and manganese. Other towns have experienced iron or manganese problems when exploring for groundwater.

When iron or manganese exceeds health standards, treatment is needed. A typical system of removal would include treatment with potassium permanganate. This oxidizes iron and manganese, with the resulting oxides and hydroxides caught on a filter bed. Recently, inground treatment of iron and manganese has been developed. Oxygen enriched water is injected into the ground periodically. This produces a zone around the well, rich in oxygen, which enables the natural bacteria to oxidize the iron and manganese, making them insoluble. Where towns face long-term iron and manganese buildup, treatment with inground systems may provide an economical long-term solution. Pembroke currently uses an inground system of iron control known as the 'Vyredox' System. Cost of the Vyredox System has been mentioned by other towns as a drawback.

Stream Corridor Development Alternative - Additional Public Access

Each of the towns adjacent to the North, South and Indian Head Rivers owns one or more parcels of public land along those rivers. However, public access, especially with boat or canoe launching facilities, is only provided on a few of these parcels and almost all of these have been restricted to town resident use. An increased number of access points may lessen the pressure on any one area of section of the river.

Public access points are limited to some bridge crossings, commercial marinas, and town-owned lands acquired by town expenditures or state and federal cost share. The state also owns a public access parcel on the Indian Head River. In summary, while numerous residential properties abutting corridor rivers have private access, including docks, public access is limited.

Access to corridor rivers and streams is necessary when optimum use of the water-based recreation amenities is desired. Recreation has been recognized as the major use of the North and South Rivers corridor since the turn of the century. Excellent water quality and scenic character have resulted in an attractive environment for swimming, fishing, boating, clam digging, and other water-based activities. Demand for these uses has been high. Boat traffic congestion, for example, has often occurred in the lower reaches of the North River on summer weekends.

The corridors and the adjacent coastal area have long been popular vacation areas with numerous seasonal commercial industries supporting recreationalists' demands, including: overnight lodging facilities, gas stations, specialty shops, and other vacation services. There are four marinas on the North River and one on Herring Brook.

Stream Corridor Development Alternative - Control of Development

The North and South Rivers corridors are relatively less developed than the river basin as a whole; however, the higher value properties are those located within the corridor and especially along the rivers and streams. Pressure to develop the river corridors is high. Controlling factors are rising land values and the large percentage of water and wetland area within the corridor. The high quality visual amenities also contribute toward the value of the corridors for development.

The greater part of the corridors is low density residential with lots larger than two acres. The number of residential lots one-half to one acre in size is increasing in corridor subdivisions. New road and street construction is limited; new streets being confined to subdivision cul-de-sacs. Most of these roads are perpendicular to the rivers; very few are parallel to the rivers.

The river corridors are viewed by local residents as being sensitive and fragile areas and numerous legal and managerial controls have been implemented by corridor communities. Zoning within the North and South Rivers corridors is largely one acre residential except for some areas near the coastal beaches. Some business and commercial zones exist within the corridor in Hanover and Pembroke at the North River/Route 53 crossing and along portions of Driftway Road in Scituate near First Herring Brook. Industrial zoning in the corridor and throughout the Basin is minimal.

Conservation and recreation zoning ordinances have been enacted in several corridor communities. Saltwater conservation and wetland zones protect the marshes along the North River in Marshfield, Scituate, and Norwell. Hanover has an overlay protection district covering floodplains, wetlands, and watershed areas and is presently considering a groundwater protection district as well. Pembroke and Scituate also have floodplain and watershed protection districts. Table 4-11 shows some local ordinances and zoning controls that are in effect for each town relating to protection of natural resources in the stream corridors.

Most towns in the North and South Rivers Basin corridors have initiated zoning measures along the corridors to protect water resource related areas from development. The local zoning provisions, however, have not been consistent throughout the corridors.

table 4-11

Local Resource Protection By-laws in North and South Rivers Stream Corridors

Town	Type of Zoning District	Conservation	Forestry	Farming	Outdoor Recreation	Water Access	Water Control	Marina	Residential	Filling/Excavating	Underlying Uses
		Permitted Uses									
Duxbury	Wetlands and Floodplain Protection	■	■	■	◪		◪				
Hanson	Agriculture, Recreation	■	■	■	◪		■	◪	◪		
Hanover	Floodplain, Wetland, and Watershed Protection	■	■	■	◪		◪				
Pembroke	Floodplain and Watershed Protection	■									■
Norwell	Saltmarsh Conservation	■					■			◪	◪
	Floodplain, Watershed, and Wetlands Protection	■	■	■	■	◪	◪				
Marshfield	Inland and Coastal Wetlands	■			■		◪			◪	◪
Rockland	No special resource districts										
Scituate	Saltmarsh and Tidelands Conservation,	■				■	■				
	Floodplain and Watershed Protection	■	■	■	◪	◪	◪				

■ Permitted

◪ Permitted only through appeal

Blank indicates that the use is not specifically mentioned in the bylaw.

There are a number of state and federal statutes and programs that also regulate or protect resources along the stream corridors. These include the Wetlands Protection Act, the Coastal Wetlands Restriction Act, the Clean Waters Act, the Federal Water Pollution Control Act, and the Scenic Rivers Act. Table 4-12 lists these statutes and the activities or resources affected by them.

Table 4-12

State and Federal Statutes and Programs Protecting Corridor Resources

Statute or Program	Resource Area Involved	Requirements and Agency Responsible
Wetlands Protection Act (Mass. Gen. Laws, Chap. 131, Sec. 40)	Removing, filling, dredging or altering land or water areas within 100 ft. of a wetland or water body.	Order of conditions needed from local town Conservation Commission.
Federal Water Pollution Control Act (Sec. 404)	Removing, filling, dredging or altering water areas considered to be "naviagable" waters including many small streams.	404 Permit required from Army Corps of Engineers.
Coastal Wetlands Restriction Act (Mass. Gen. Laws, Chap. 130, Sec. 105)	Dumping, excavating, dredging, or altering any properties restricted by statute, some uses and construction allowed.	Order of restrictions established on specific property.
Clean Waters Act (Mass. Gen. Laws, Chap. 21, Sec. 27)	Discharge of water pollutants to rivers, streams, and groundwater.	Permits granted on amount of pollutants according to standards set by Division of Water Pollution Control.
Coastal Zone Management Program	Any activities designated for preservation or restoration which are subject to review by the Executive Office of Environmental Affairs and its associated agencies.	Appropriate review by EOEA agency applying CZM policies.
208 Water Quality Management Program (P.L. 92-500 Sec. 208)	Point and non-point sources of pollution affecting rivers, streams, and other water bodies.	Discharge permit granted under Environmental Protection Agency or state agency designated.
North River Scenic Rivers Act	Approximate 300 ft. strip on either side of North River, including some tributaries and wetlands; specific use regulations in North River Protective Order.	Permit required by North River Commission.
Inland Wetlands Restriction Act (Mass. General Laws Chap. 131, Sec. 40A)	Dumping, excavating, dredging, or altering any properties restricted.	Restrictions established on specific properties.

Stream Corridor Development Alternative - Management of Publicly-owned Lands

A substantial amount of land is in public or quasi-public ownership in the North and South Rivers Basin. Approximately 8,900 acres are in town, county, state, or federal ownership. Table 4-13 shows public and quasi-public lands grouped by ownership or major use for the North and South Rivers Basin. Total public and quasi-public land is 12,500 acres or 12.5 percent of the total land area of the basin towns.

Table 4-13. Public and Quasi-Public Lands.

Public Lands	Acreage	% of Basin
Major Parks and Playgrounds	36 ac.	< 1%
Major School Department Lands	1,241 ac.	1.2%
Conservation Commission Lands	3,845 ac.	3.0%
Public Beaches	80 ac.	< 1%
Other Town-owned Lands	2,313 ac.	2.3%
County-owned Lands	70 ac.	< 1%
State-owned Lands	484 ac.	0.5%
Federally-owned Lands	820 ac.	0.8%
Total Public Lands	8,889 ac.	8.9%
Quasi-Public Lands		
Golf Courses	963 ac.	1%
Sportsmen's Clubs	750 ac.	0.7%
Camps	1,193 ac.	1.2%
Other Quasi-Public Lands	704 ac.	3.6%
Total Quasi-Public Lands	3,610 ac.	3.6%
Total Public and Quasi-Public Lands	12,499 ac.	12.5%

Of the total public lands 18 percent, or roughly 1,600 acres, are located within the stream corridor. Most of these holdings were originally acquired for conservation purposes and/or have some historical significance.

Of the public lands within the corridor, very few have been developed for formal public recreational uses. In some locations, informal trails have been blazed or river/stream access areas created by local users. While local residents are aware of the locations and recreational opportunities in these public lands, the opportunities for recreational use are not widely publicized.

The lack of recreational development may stem from the original purposes for acquiring these lands. Many towns have been hesitant to develop recreational facilities on lands originally acquired for conservation or other resource protection purposes. Local objection has been expressed against intensive public use of the river corridors. This is related to the public's perception that intensive recreation is incompatible with resource area protection. Passive recreation, however, is viewed as being more compatible with resource protection, especially with proper design and management.

Acquisition programs on the part of basin communities have been active in past years. Towns now own many sites. Funding has been principally borne by town expenditures. State expenditures have also helped towns acquire land. Self-help funds have come to Scituate and Marshfield among others. Residents have further supported these with bequests and other gifts of land for conservation purposes. Due to rising land values and the limiting of tax revenues, basin towns have not been able to continue to fund such acquisitions as they have in the past. As a consequence, alternative funding sources and aids need to be explored for each resource area flagged for future acquisition.

Moreover, alternative methods for protecting resources other than acquisition, such as zoning, may represent a more logical approach. Analyses of exisiting corridor public lands and resource protection needs, performed through individual town open space plans, indicate that very little additional land needs to be purchased. The Control of Development portion of the Stream Corridor Development section of this report describes the role of zoning and other resource controls as alternatives to fee simple acquisition.

In addition to passive recreational needs and acquisition programs, corridor public lands need management. Management plans for woodland and wildlife habitat have been developed and implemented for some town lands, but generally are lacking for the majority of public holdings.

Stream Corridor Development Alternative - Scenic and Recreational River Protection Order for the North River

The Massachusetts Legislature passed General Laws Chapter 21, Section 17b, The Scenic and Recreational Rivers Act, giving the Commissioner of the Department of Environmental Management (DEM) authority to adopt orders regulating certain areas on or along rivers and streams.

The North River was selected as a "demonstration project" for the Act. A local citizen advisory committee was formed to advise DEM staff and review proposals. The Committee assisted with the drafting of the Protective Order for the North River and provided a public relations information program in the North River area.

The Protective Order for the North River was adopted in March 1979, and was subsequently recorded on the deeds of landowners. The North River became the first designated Scenic and Recreational River in the state and provided an opportunity to develop appropriate regulations and an implementation strategy for the program. The North River Commission, authorized under Massachusetts General Laws Chapter 367, Section 62 of the Acts of 1978 and comprised of selectmen and their designees from each town along the river, administers the program.

The Protective Order established the North River Commission and regulates, restricts, or prohibits uses and activities in the Scenic and Recreational River Corridor along the North River and parts of associated tributaries.

Specific land uses that do not degrade the scenic and recreational character of the river corridor are permitted under the Order. Special permit uses are allowable if they will not involve: substantial degradation of water and air quality; harmful alteration of wetlands; increase in erosion or sedimentation; danger of increased flood damage or obstruction of flood flow; overcrowding; noise; obstruction to navigation; danger to fish and wildlife habitat; despoliation of the corridor's irreplaceable wild, scenic, and recreational river resources; impairment of the natural visual quality of the corridor; or damage to private or public property.

The Order essentialy prohibits or severely restricts industrial and manufacturing use of the corridor and limits activities that would tend to detract from the natural visual quality of the North River corridor.

Site design standards are specified to insure that permitted development of the corridor will be compatible with scenic and recreational use. The Order also establishes rules and regulations concerning pesticide and fertilizer use and erosion control.

Areas Sensitive to Development Alternative - <u>Protection of Sensitive Areas</u>

Local action to control development and protect resources derives from one of three governmental powers - the power to regulate the use of property, the power to acquire property, and the power to tax. The power to regulate is derived from the police power and is transferred to zoning practices. It permits the town to control the use of property in the interest of public health, morals, safety, or the general welfare. The power to acquire private property may be used by the town when the acquisition is for a public use or purpose. The power to tax may also be used to support measures for controlling land use.

The use of police power, or zoning, can be effective in controlling development. Sensitive areas or critical resources can be defined through a well constructed zoning ordinance. Certain types of zoning can serve both to protect resources and to direct growth to areas not as sensitive or valuable. Zoning does not insure permanence for protecting sensitive areas since an overriding vote or variance could change the designated use of a parcel of land. Rezoning an undeveloped area as an open space or conservancy district can be of significant value. In placing a "holding zone" on the area, the town might be able to gather, through its capital budget, funds for acquisition. To be considered viable, zoning needs to be justified as contributing directly to the health, safety, and general welfare. Arguments frequently used in opposing a zoning ordinance cite unconstitutionality based on arbitrary and unreasonable grounds or taking without just compensation.

Specific types of zoning that can be used effectively to aid in resource protection and control of development include floodplain zoning, wetlands zoning, agricultural zoning, watershed zoning, groundwater zoning, conservation zoning, etc. Large lot zoning could also be considered, but it is not always socially acceptable or economically viable. Overlay districts that do not necessarily change existing zoning can be superimposed so as to add further restriction on uses that would conflict with resource protection. Overlay districts have tended to be less difficult to enact than revisions of existing zoning.

Subdivision regulations are another regulatory device which could be effectively used to maintain vulnerable areas in a more natural state. Rules and regulations are adopted by local planning boards and may be easier to change than zoning which requires a two-thirds vote of a town meeting. The existing subdivision regulations are such that very little sensitivity toward the natural resources of a site is required. Requirements should be placed on developers to prepare detailed plans of their sites which illustrate soil, water, topography, vegetation, and wildlife conditions. Their development schemes should then be presented to the Planning Board, Conservation Commission, and Health Board simultaneously. To use subdivision regulations more effectively certain performance standards could be established as an aid in preserving and enhancing resources.

Performance standards attempt to define relationships between various land uses and to establish criteria for use in guiding the location of future land use. Performance standards can prevent disparities in tax policy within a developing community by permitting recreation and agricultural land use in areas of normally higher tax assessments and basing assessments on uses allowed through such standards rather than the uses usually allowed as of right. Performance standards serve as a valuable tool because, unlike conventional zoning practices which fix a use to an area, they are flexible enough to assign uses to land as it becomes available for development. Developers, therefore, would be required to demonstrate that their plans satisfy pre-determined criteria. In order to evaluate such a development plan, zones of vulnerability to land use impact must be defined.

Of the several types of zoning previously mentioned, conservation zoning could probably offer the most flexibility to the town. Conservation zoning is used to preserve unique ecological, scenic, and other natural or sensitive areas which would benefit from protection or preservation. Since conservation zoning is subject to pressures for change, it can be used most effectively during a period when the town takes necessary steps to purchase these areas. Conservation districts, applied to ponds and streams, wetlands, floodplains, etc., are clearly well suited to the continued protection of the public health, safety, and general welfare. Such zoning could protect surface and groundwater quality and quantity, and, at the same time, preserve important vegetation and wildlife habitat.

Private property can be purchased for resource protection provided that the land is for public use and purpose. Land can be acquired through fee simple acquisition, the best but also the most expensive way to protect resources.

When money is scarce, installment purchases could be used to acquire lands. The difference is in timing and not in the ultimate interest acquired. Once the installment payments have been made the town will have a fee simple interest in the land. This technique would allow the town to establish a price based on fair market value before development and to spread costs over a longer period of time. An important advantage to installment purchase is that more land could be acquired ultimately than if fee simple were used. A disadvantage is the debt incurred and the resulting interest requirements.

Installment purchase agreements also apply to the reservation of land. Reservation refers to land set aside with an option to buy during a specified time period. Landowners would be insured payment for their land through such an agreement. Normally, reserved land can neither be developed nor sold.

Tax incentives may be used to encourage landowners to retain their properties for conservation uses and/or sell their land to public agencies for conservation purposes. Techniques such as lowered assessment, or deferral of taxes, can be used as incentives. Lowered tax assessments are generally used in conjunction with conservation easements. In return for disallowing development on his property, a landowner may be granted a lower assessment on his property taxes. Tax deferrals are normally graduated over a specified time period and eventually lead to purchase, bequest, or easement. Deferrals can occur over 5, 10, 20, or 30-year periods with taxes either gradually decreasing to a lower assessment or beginning with a lower assessment and increasing back to the original assesment (whichever is preferred by the landowner). After the time period runs out, a new agreement would need to be developed with the landowner.

A tax deferral incentive could also encourage gifts of land. If those who own land in a designated conservation or critical resource district donate their land to the town, they would not be required to pay taxes on it and they could also benefit from a federal income tax deduction for land given for a public purpose. The term "gift" applies to outright gift, gift with life estate, or gift to take place after the donor's death. Tax deferrals can be complicated by the roles and discretion of the board of assessors and of the agency which acquired the land.

Voluntary contractual agreements, such as easements or rights-in-land, are very useful for preserving the natural and sensitive areas. There are essentially two kinds of conservation easements - scenic or strip easements, and blanket easements. Scenic or strip easements are effective in preserving views from highways, pedestrian ways, and stream corridors and in preserving parcels of land that are best suited for conservation while blanket easements preserve specific uses or resources on most any lands. Both types of easements must be permanent if the landowner is to receive a lower tax assessment. The cost of easements may be considerably less than the cost for fee simple acquisition. Another useful device is that of transferring to a public agency one or more rights from the package of rights which comprise fee title. For example, a landowner could relinquish his "right to dredge and fill or build structures on his property," thereby helping to preserve the value of the resources his land contains. This transfer of rights is usually combined with a tax incentive agreement to compensate for the loss of some rights of land.

Restrictive covenants are another tool useful in implementing a resource protection strategy. Restrictive covenants are purely voluntary and cannot result from government action. This mutual agreement between two or more parties can be used to limit or restrict the use of land to better foster natural resources Thus, neighbors could bind themselves and their successors-in-title to specific limitations on the use of their property. This tactic alludes to a form of administrative implementation strategy which is based on close contact and communication with private interest groups and landowners.

It is obvious that no one technique or strategy could be independently effective in protecting resources or in controlling development in all cases. Certain strategies will work better with different landowners and different parcels of land. The approach of using different methods or combinations of methods is suggested. Innovativeness and skill in negotiating are important for a successful conservation program. The search for an agreeable blend of techniques is one which will continue throughout the Basin's resource planning program.

Areas Sensitive to Development Alternative - Specific Options

This section provides information concerning possible options that could be used to reduce or control potential adverse effects of development on sensitive areas. The alternatives consist of developmental regulations, purchase of sensitive areas, institutional arrangements, and data sources designed to address the needs of a particular sensitive area. Table 4-14 contains a summary of the alternatives discussed. Most of the alternatives have been utilized in at least one of the Basin communities, but there has been only a limited degree of sharing of experiences, successes, and failures between towns. The inter-town cooperation and sharing of ideas would be an excellent first step toward offering more protection to development-sensitive areas.

Table 4-14

Summary of Alternative Options
Development-Sensitive Areas

Area Sensitive to Development	Options to Reduce or Control Potential Adverse Effects of Development
Soils with limitations for disposal of septic tank effluent	Use of Soil Survey data and effective percolation testing. Municipal sewerage for areas with severe limitations for disposal of effluent.
Prime farmland soils	Purchase of development rights to agricultural land. Assessment of farmland under the Agricultural & Horticultural Assessment Act.
Wetlands	Control of wetland alteration under provisions of the Wetlands Protection Act. Restriction of wetland development through the Wetland Restriction Act. Protective zoning of wetlands.
Flood plains	Continued participation in the National Flood Insurance Program including flood plain construction regulation.

Soil Surveys Alternative

Soils in Plymouth County have been mapped by soil scientists and soil maps are published for the entire county in the Soil Survey of Plymouth County, Massachusetts. The soil survey provides detailed information concerning the geologic development, physical characteristics, and location of the various soils found in Plymouth County.

The tables of physical data indicate various properties of the different soil groups and also provide interpretations of the limitations for certain uses imposed by the soils. The tables indicating limitations for septic tank absorption fields, and those indicating permeability, are of special interest to officials concerned with proper siting and operation of septic tanks and leach fields. These data can be helpful in the preliminary evaluation of an area for septic tank sewage disposal by alerting officials to potential problems and indicating the need for extra diligence in conduting on-site investigations.

The soil survey data and maps do not eliminate the need for on-site investigations of soil conditions for a particular use. Because of the map scale used in the report, small areas of soils that differ from the dominant soil may not be reported. These small areas may have significantly different characteristics affecting the use of the area for septic tank disposal of effluent. A program of accurate percolation testing is necessary.

Municipal Sewerage Alternative

The problems that can occur when soils with limitations for disposal of septic tank effluent are developed can be minimized if community sewage collection, treatment, and disposal are employed rather than individual septic tanks. Of course, the cost of installing a municipal sewerage system is many times more expensive than that for an individual septic tank system. The cost difference becomes even greater in rural and suburban areas where houses are not close together and costs for long lengths of sewer lines are incurred.

In many towns, sewer lines are only extended to an area after development has occurred, septic tanks are failing, residents are complaining, and regulating agencies are demanding that the town take action. An alternative to this scenario would have the community require municipal sewerage in subdivision areas where soil limitations are severe, or even moderate, if housing density is high enough to indicate a high probability of potential sewage disposal problems.

Installing sewerage facilities in anticipation of a possible need would be quite wasteful unless development densities were increased to take advantage of the sewers. The installation of sewers offers opportunities for shaping development and preserving open space.

Agricultural and Horticultural Assessment Act Alternative

Massachusetts General Laws, Chapter 61A, Sections 1-24, provide for the imposition of lower property taxes upon farmland that meets certain criteria. The Act thus provides an economic incentive and assistance to maintain the land in its agricultural status. Tax rollback provisions discourage use of the Act to temporarily shelter land pending development, yet are not a major disincentive to the bonafide farmer who sells his land at a later date after having been in the program for a number of years. The Act also contains a provision giving the community the right of first refusal to purchase a parcel assessed under Chapter 61A if the owner receives an offer from a prospective purchaser.

In the past when many communities valued land at less than fair market value, Chapter 61A was not utilized to the extent it is today since a de facto agricultural value assessment situation existed. Now that towns are valuing property approximately equivalent to market value, the lower agricultural use assessment becomes more important to the owner of farmland.

Although the Agricultural & Horticultural Assessment Act provides financial assistance to maintain land in agriculture, it is probably not a significant deterrent to conversion to urban uses since the penalties for conversion are not severe in relation to the monetary returns possible from conversion. However, the lower property taxes may provide enough of an incentive for a marginal farm to stay in farming rather than abandoning the farmland to forest. Chapter 61A may remove the interim tax pressure to sell agricultural land but the Act cannot ease the problem of foregone income as Chapter 780, the Agricultural Preservation Act, can.

Massachusetts General Laws, Chapter 61, Sections 1-7 - The Classification and Taxation of Forest Lands, provides that landowners who have at least 10 contiguous acres of forestland having a value not over $400 an acre (land and timber) may apply to their local tax assessors to have their forestland classified under the law. If the state forester determines that the woodland owner qualifies, the land and timber are taxed separately. The land is assessed at not more than $10 per acre and annual taxes are paid on this basis. Also, a forest products tax of eight percent is paid on the value of forest products harvested. A tax rollback applies if the land is withdrawn from the forest classification.

The Forestland Classification Act provides another method to assist landowners to maintain their land in an undeveloped state. Since prime farmland soil that is maintained in forest cover is assumed to be potentially available for farmland conversion, the Act might be indirectly used to protect prime farmland soils.

Agricultural Preservation Act Alternative

Massachusetts General Laws, Chapter 780, authorizes the purchase of development rights on farmland to limit farmland use conversion, and generally encourage the retention of a viable agricultural base in the state.

Governmental purchase of development rights to agricultural land removes the financial pressure on a farmer to sell his land for non-farm use by compensating the owner for the nonagricultural value of the land. The purchase also helps to insure that the land will remain an operating farm by providing working capital to the operator and insuring that a subsequent purchaser will likely also be a farmer.

There is a great deal of competition for the limited amount of funds available for development rights purchase. Community interest and support for the concept of agricultural development rights purchase is an important factor in deciding where the available funds will be committed.

Wetlands Protection Act Alternative

The Massachusetts Wetland Protection Act (Massachusetts General Laws, Chapter 131, Section 40), has been a major factor in reducing the rate of wetland loss throughout the state. The Act is administered by the Conservation Commission in each community and the effectiveness of the Act depends primarily upon the dedicated individuals who comprise the Commissions. If these people respond to pressures for development, the valuable wetland resource can be compromised for future generations; if they are diligent in their deliberations, wetlands will only be altered when the trade-offs result in a positive benefit to the community. The Wetlands Protection Act provides for some flexibility to permit a community to exercise local judgment and consider local values and priorities in accepting or rejecting wetland alteration. Weighed against the benefits of this local control is a certain degree of danger that local pressure may result in the Conservation Commission accepting wetland alterations that are not in the town's long-term interest. Likewise, changes in the composition of personnel on the Conservation Commission can result in drastic changes in philosophy regarding wetland protection. Although the Division of Environmental Quality Engineering maintains an oversight function in the wetland protection process and can overrule the local decisions through an appeal process, the Conservation Commission remains the first line of wetland defense. If the Wetland Protection Act is to remain a usable tool in resource protection, the basin towns and their Conservation Commissions must continue to recognize the many tangible and intangible benefits accruing from wetland protection.

Wetlands Restriction Act Alternative

The Wetlands Retriction Act (General Laws, Chapter 130, Section 105) has been implemented in Duxbury, Hanover, Norwell, and Pembroke to protect coastal wetlands through the filing of deed restrictions that severely limit the development potential of the wetland areas and may offer more protection than provided by the Wetlands Protection Act. Inland wetlands may also be protected under provisions of the Inland Wetlands Restriction Act (General Laws, Chapter 131, section 40A).

The Restriction Act is administered by the Massachusetts Department of Environmental Management and requires a substantial investment in wetland mapping, identification, preparation of legal descriptions, and the actual preparation and filing of restrictions. Cooperation by local officials is essential if the restriction program is to proceed and be successful.

The mapping of wetlands and the identification of wetland types has been completed and the data are available in the form of photographic maps at scale 1:5000 for communities in the North and South Rivers Basin. These wetland maps will be used in the Wetland Restriction Program and should also be helpful to the local Conservation Commissions in administering the Wetlands Protection Act.

Although the mapping of wetlands has been completed, a great deal of work remains to determine the relationship of the wetland areas and individual property parcel boundaries. After this is completed, hearings need to be held and property owners notified before the actual deed restrictions are filed.

After restrictions have been filed, they may be removed at a later date for adequate cause. This procedure normally involves a hearing and a determination by the Department of Environmental Management that sufficient public benefit will result to warrant removal of the restriction. In contrast to the pure police power basis of the Wetlands Protection Act, the restriction program has limited provisions for payment of compensation upon a court order.

Protective Zoning Alternative

Communities have long utilized protective zoning to regulate land use and to encourage land use that is compatible with adjacent land uses and natural resource constraints. The Zoning Enabling Act, Massachusetts General Laws, Chapter 40A, permits a municipality to promote the health, safety, morals, and general welfare of the community through zoning and, among other things, to encourage the most appropriate use of land and to preserve and increase the amenities.

Some wetlands in the North and South Rivers Basin towns are protected through the use of zoning but protection varies from town to town. Marshfield identifies the majority of wetlands in two overlay districts for Coastal and Inland Wetlands; Hanson has a "Recreation Agriculture" district encompassing a large percentage of the wetlands in town, but a significant wetland area is zoned for industrial use; Norwell has the North River wetlands in a "Saltmarsh Conservation" district; Duxbury's wetlands are in a "Wetlands Protection" District; while the Scituate coastal wetlands are in a Conservation District and many of the inland wetlands are included in the Flood Plain and Watershed Protection District.

Zoning to protect wetlands against development appears to be a viable option in the other communities which have no wetland zoning at present. Towns with only a small portion of their wetlands protected by wetland zoning districts or overlays could also consider extending the districts to include all significant wetland areas in the town.

Appendix I

RESOURCE BASE

Study Area Location

The North and South Rivers Basin is located about 15 miles south of Boston and is almost entirely within Plymouth County, Massachusetts. As indicated on the Location Map (Figure I-1), the Basin includes major portions of eight towns and minor portions of an additional four communities. The Basin covers about 73,000 acres or 114 square miles, and is located within the Massachusetts Southern Coastal Drainage (Hydrologic Unit Code 0109002).

For purposes of the River Basin Planning Program, the study area encompasses the towns of Duxbury, Hanover, Hanson, Marshfield, Norwell, Pembroke, Rockland, and Scituate. Resource inventories and evaluations were made for the entire area included within the boundaries of those eight towns. Some pertinent physical data concerning the Basin and communities are presented in Table I-1.

Table I-1

Physical Data

Town	Town Area (Acres)	Area Within North-South Basin (Acres)	% of Town Area in the Basin (Acres)
Duxbury	15,454	6,810	44
Hanover	9,978	9,980	100
Hanson	9,971	4,200	42
Marshfield	18,678	17,960	96
Norwell	13,133	10,900	83
Pembroke	15,284	10,910	71
Rockland	6,421	5,790	90
Scituate	11,281	5,060	45
Abington	6,510	790	12
Hingham	14,500	100	1
Weymouth	11,740	290	2
Whitman	4,410	90	2

Climate

The average annual precipitation is about 44 inches, that is evenly distributed throughout the year (Figure I-2). The Basin does not have "rainy" and "dry" seasons. The average monthly precipitation varies from just under 3 inches to near 4 1/2 inches. Part of the winter precipitation is snow which averages about 40 inches per year. About 50 percent of the precipitation is transformed to surface runoff resulting in an average annual runoff of about 22 inches.

The average annual temperature is approximately 50 degrees Fahrenheit (°F), with an average in January of about 30°F, and July of about 71°F. Sea breezes have a significant influence upon the climate along the coast. However, the prevailing easterly winds quickly decrease this effect inland. The growing season (frost-free period above 32°F threshold) varies from an

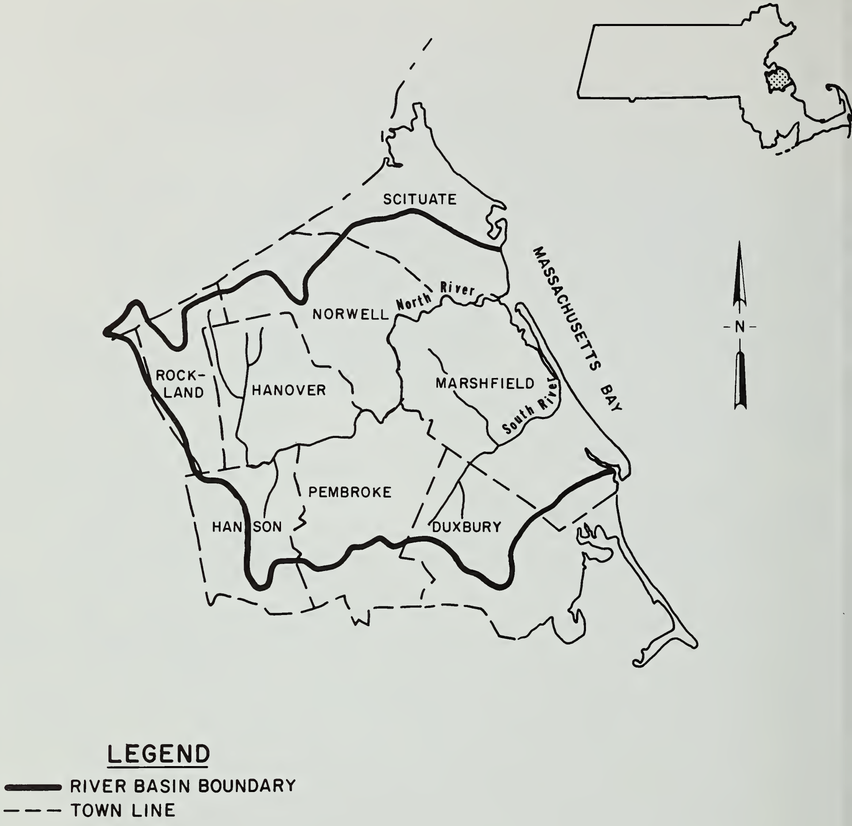


Figure I-1

LOCATION MAP
NORTH-SOUTH RIVERS BASIN
MASSACHUSETTS RIVER BASIN PLANNING PROGRAM
1982

average of about 200 days on the coast to only 160 days inland. Along the coast the mean frost-free period is from early April to early November, and inland from late April to early October. The climate in the area varies widely from day-to-day and year-to-year and weather averages can be misleading.

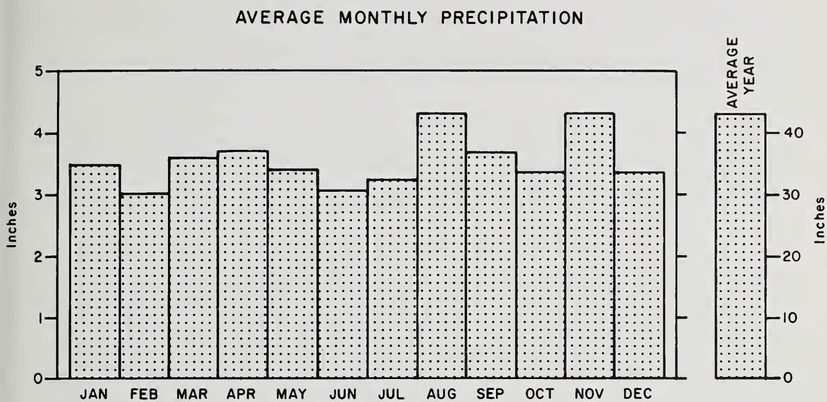


Figure I-2

From Hydrologic Investigations Atlas HA-504, U.S. Geological Survey, 1974.

Land

a. Topography

The Massachusetts Coastal Zone Management program refers to the North River as "one of the most scenic rivers on the Massachusetts coast." Along the shore, beach and dune deposits are interrupted by low hills, some of which have been eroded into sea cliffs by tidal action. The inland areas along the estuary of the North and South Rivers are bordered by naturally productive salt marshes. The upstream watershed contains flat gradient streams, which drain the extensive inland wetlands of the Basin. The highest elevations are 150 to 210 feet above mean sea level.

b. Geology

Eastern Massachusetts geologic history before the Pleistocene Glacial Epoch is not well known due to widespread coverage of the bedrock surface by glacial materials. Some geologic relationships can be inferred based on rock outcrops visible in adjacent areas. Rock as old as Pre-Cambrian represent a long period of geologic mountain building and subsequent erosion of the land surface. The more recent geologic history is represented by deposits of the Pleistocene Glacial Epoch which were superimposed on the older scoured bedrock surface. Advances, retreats, and readvances of glacial ice resulted in further scouring of the bedrock surface. The glacial drift or sediment was deposited on this highly irregular surface. As ice was melting from the receding glacier, meltwater further sorted and distributed the glacial drift, resulting in deposits of sand, gravel, silt, and mixtures of the three.

Drainage patterns which existed prior to the advance of the glaciers were altered resulting in a superimposed post-glacial drainage pattern. These streams are now sorting the glacial drift into the alluvium present in the stream channels.

Geologists classify glacial drift into two major types: stratified and unstratified. The composition of till is an unstratified mixture of sizes ranging from clay to boulders. Thickness of till is somewhat dependent upon the depth of preglacial scouring of the bedrock surface. Generally, thickness of till is greatest in lowlands and thinner at higher elevations.

Stratified glacial drift is classified as either ice contact or outwash, depending on its location of deposition. Ice contact stratified drift shows by its rapid change in material sizes and deformation that it was deposited near masses of glacial ice. These deposits consist mostly of sand and gravel; however, variability both laterally and vertically is normal. Landforms distinctive of ice contact deposits include eskers, kames, and crevasse fillings. Outwash deposits are water-laid stratified drift that was built beyond the glacier. Textures consist of sand and gravel layers. In the North and South Rivers Basin they were deposited in lowlands in front of the glacial ice.

Lake bottom deposits are represented mostly by finer grained sediments formed in temporary glacial lakes. These deposits are usually stratified silts, clays, and fine sands, accumulated during seasonal deposition cycles.

Clays and clayey silts were deposited following deglaciation of the area during the rise in sea level. Distribution of these marine silts and clays is limited to near coastal and tidal areas adjacent to the North and South Rivers.

Organic soil deposits are representative of accumulations of peat and decomposed organic debris in valleys, lowlands, and in some poorly drained depressions in glacial till.

Alluvium is the result of post-glacial stream erosion and sedimentation processes. Grain size is dependent on both the material being eroded, and the velocity of the stream transport system. Therefore, wide ranges in soil properties are exhibited by alluvium.

c. Soils

The soils of the North and South Rivers Basin have formed in materials influenced by glaciation. The Basin's many upland hills and ridges are mantled with two or three feet of friable, loamy or sandy material underlain by firm or friable, loamy or sandy, heterogenous glacial till. Stones and boulders are normal surface features in wooded areas. Bedrock outcrops are common, especially on steeper slopes.

Intermingled with the uplands, in valleys and lower positions and on relatively broad plains, are soils formed in materials influenced by glacial meltwater. Slopes in these areas range from nearly level to moderately steep. The soils are quite varied, but all have substrata of sand or sand and gravel. The surface soils and subsoil portions may be silt, loamy or sandy, and contain varying amounts of gravel. Minor areas along the mid to southeast portions of the Basin include beaches, tidal marshes, and sand dunes.

The general soil map for the North and South Rivers Basin is on Figure I-3. Five soil associations are included:

1. The Tidal Marsh-Dune Land-Coastal Beach association consists of tidal marshes, small dunes, and sandy beaches. It occurs along the coastline in the mid to southeast portions of the Basin and along the North and South River corridors and occupies about 14.6 percent of the total acreage in the basin towns.

   The largest areas of tidal marsh are in Duxbury, Marshfield, and Scituate. Some of the larger marshes are protected along their seaward edges by barrier beaches, bay-mouth bars, or other similar formations such as Duxbury Beach and the Humarock. Tidal marsh varies greatly in composition. Some areas consist mainly of organic material, others of mineral material, chiefly silt and clay. All areas are partly or completely flooded twice daily.

   Coastal beach formed from highly quartzose sand that was transported and sorted by the action of wind and waves. The dunes commonly are few and small.

   Tidal marsh is valuable as habitat for various kinds of waterfowl, for some mammals, and for many marine organisms. Coastal beach provides valuable recreation areas.

2. The Quonset-Hollis-Bernardston association which occupies about 4.6 percent of the basin towns area occurs in the north, chiefly in the town of Scituate. It is characterized by small irregular hills and knobs from which bedrock outcrops; by smooth rounded hills called drumlins; by level plains; and by steep terraces.

   Quonset soils are on droughty, level plains and steeply sloping terraces. Hollis soils occupy the shallow-to-bedrock parts of the knobby hills and are intermingled with deep, well drained Charlton soils. Bernardston soils are on drumlins. They are deep, well drained soils underlain by firm, platy glacial till. Warwick soils, which are similar to the Quonset but finer in texture, are important secondary soils on the plains and terraces. Other important secondary soils are the moderately well drained Scituate and the well drained Essex, which are also on drumlins, and the very poorly drained muck soils, which are in depressions.

   This association is used principally for residential developments and for woodland. Proximity to Boston has resulted in much of the previous farmland being converted to homesites. The woodland consists of fairly good mixed stands of hardwood and white pine.

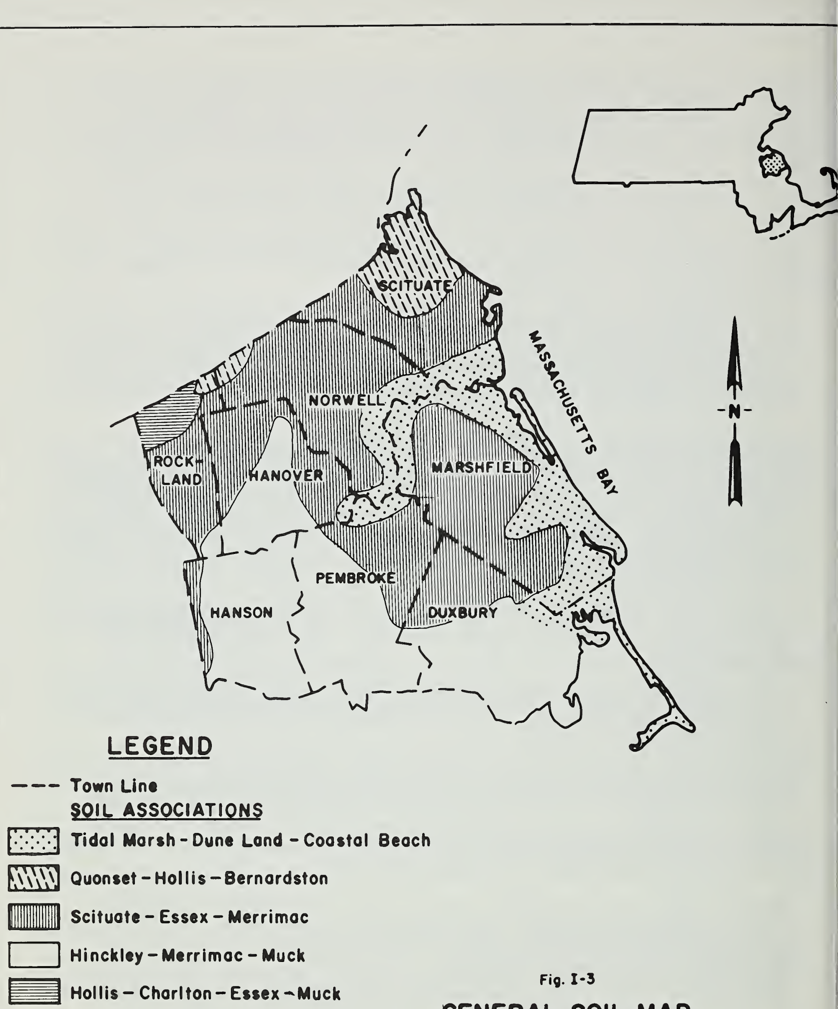


Fig. I-3

GENERAL SOIL MAP

NORTH-SOUTH RIVERS BASIN

MASSACHUSETTS RIVER BASIN PLANNING PROGRAM

1982

Scale 1:250,000

0 5 10 15 Miles

3. The Scituate-Essex-Merrimac association which occupies about 46.4 percent of the basin towns area extends across the northern and east central portions. Hills and ridges are interspersed among broad, low-lying plains and terraces. The slopes for the most part are gentle to moderately steep. A few are steep.

The Essex and Scituate soils occupy the uplands. They are deep, gently sloping to moderately steep coarse sandy loams underlain at a depth of 10 to 30 inches by firm, but coarse, glacial till. The Merrimac soils occupy the nearly level plains and terraces. Important secondary soils are droughty, gravelly Hinckley soils; very poorly drained, stony Brockton soils; and very poorly drained Muck.

Much of this association is used for residential purposes, a small acreage is used for hayland, and the rest is forested with mixed stands of hardwoods and white pine. Seepage is prevalent throughout the association because of the firm underlying till.

4. The Hinckley-Merrimac-Muck association which occupies about 32.9 percent of the Basin is most extensive in the southwestern and southeastern parts. It consists of broad, low ridges; nearly level plains and terraces; and knobby, irregular ridges. Intermingled with these are extensive low, flat, wet areas.

The soils in this association formed mainly in glaciofluvial sand and gravel. Hinckley soils are deep, excessively drained gravelly loamy sands on gentle to steep slopes. Merrimac soils are well drained and somewhat excessively drained sandy loams underlain by sand and gravel. Muck is an organic soil that occurs in low-lying areas.

Much of this association is forested with fairly good stands of white pine, although new residential construction is widespread. The numerous clear, sandy-bottomed ponds provide recreation. The chief farming enterprise is the production of cranberries. Small acreages are used for beef and horses and for market gardens.

5. The Hollis-Charlton-Essex-Muck association forms a narrow strip along the northwestern edge of the river basin. It makes up about 1.5 percent of the total acreage. Irregular knobs and smooth, rounded hills are interspersed with low-lying muck flats. Slopes for the most part are gentle to moderate. A few are steep. Bedrock is exposed on the knobs.

The soils of this association formed chiefly in stony glacial till. The Hollis and Charlton soils are fine sandy loams. They occur on irregular, knobby hills where outcrops of bedrock are common. The Essex soils are well drained coarse sandy loams, underlain at a depth of 24 to 30 inches by firm glacial till. Muck is an organic soil that formed from decayed plant remains. The droughty Hinckley and Gloucester soils are important secondary soils.

Much of this association is used for residential purposes. The remainder is primarily forested with mixed stands of hardwoods and white pine. Water seepage is common in areas that are underlain by till.

d. Flood Plain Land

Flood plains constitute more than 20 percent of the eight basin towns area or over 21,000 acres. Flood plains include water and land subject to flooding by a 1 percent chance flood. Tidal flooding is predominant in the coastal towns and for miles inland along the North and South Rivers. Over 50 percent of the flood plains are subject to tidal flooding. Table I-2 gives flood plain data and shows status of Flood Insurance studies.

Use of flood plain land varies greatly depending upon the frequency, depth, and type of flooding. Frequent flooding, wave action, and salt water limit use along the coast to such things as fish and wildlife habitats, recreation, and fishing. Salinity in the rivers and estuaries varies greatly depending upon distance from the ocean, amount of fresh water coming in, and whether it is high or low tide. Tide water affects salinity as far inland as 12 miles in the North River and over 7 miles in the South River. Inland, where fresh water prevails, other uses such as cranberry bogs, pasture, etc. are compatible with the natural functions of the flood plains.

Flood plains are a unique and crucial part of any river system. The natural use of the flood plain is to temporarily hold excessive flood waters, thus reducing flood stages downstream. The flood waters in return leave topsoil and nutrients maintaining conditions for vegetative growth. This in turn produces habitat and food for fish and wildlife and is a source of nutrients for the downstream ponds and estuaries.

e. Prime and Unique Farmland

Prime and unique farmland represents land which serves or could serve an important production function and whose value would be lost if changed to an irreversible use such as homesites. The continuing loss of farmland in the North and South Rivers Basin, coupled with the increasing pressures for homesites and related services, places prime and unique farmlands into the "sensitive areas" category.

Two types of farmland were inventoried:

1. Prime Farmland - Prime farmland is land best suited for producing food, feed, forage, and fiber; and also available for these uses (the land could be cropland, pastureland, rangeland, forestland, and other land, but not urban, built-up land, or water). It has the soil quality, growing season, and moisture supply needed to produce sustained high yields of crops economically when treated and managed, including water management according to modern farming methods.

2. Unique Farmland - Unique farmland is land other than prime farmland that is used for the production of specific high-value food and fiber crops. It has the special combination of soil quality, location, growing season, and moisture supply needed to produce sustained high quality and/or high yields of a specific crop when treated and managed according to modern farming methods. In the North and South Rivers Basin, cranberries are the major unique farmland crop.

Table I-2

Flood Plain Land

Town	Flood Plains (1% chance)			Flood Insurance Program Status - January 1982			
	Total (acres)	% tidal	% of town	Entered Emergency Program	Detailed Study Began	Entered Regular Program	Contractor Performing Detailed Study
Duxbury	4,000	32	26	8/30/74	9/13/78	5/27/76	Corps of Engineers Harris Toups (PRC Harris)
Hanover	2,150	6	22	7/26/74 8/23/77	9/26/78		Resource Anal., Inc. & E.C. Jordan & Don Perkins
Hanson	500	0	5	11/8/74	9/26/78		"
Marshfield	6,300	95	34			8/30/74 4/15/76	Corps of Engineers
Norwell	3,000	26	23	8/16/74 10/22/76	9/26/78		Resource
Pembroke	1,540	0	10	7/26/74 9/3/76	6/26/75	8/10/78	Camp Dresser & McKee
Rockland	650	0	10	6/28/74 7/30/76	9/26/78		Resource
Scituate	3,510	85	31		7/13/78	9/6/74	Harris Toups
Study Area	21,650						

The Basin contains significant acreage of prime and unique farmland as well as land of importance to state and local agriculture. The following table illustrates the prime farmland soil that is actually or potentially available for agricultural use. This land includes that presently in agricultural use or forest and excludes urban and water areas.

Table I-3

Prime Farmland Soil Actually or Potentially Available for Agricultural Use

Town	Prime Farmland Soil Not in Urban Land Use in 1980 (Acres)	Percent of Town Area
Duxbury	640	4
Hanover	780	8
Hanson	670	7
Marshfield	960	5
Norwell	790	6
Pembroke	960	6
Rockland	140	2
Scituate	290	3

4. <u>Water Quality & Quantity</u>

a. <u>Surface Water</u>

There are two major drainages in the study area. These are the North River which drains over 50 percent of the area and the South River which drains around 20 percent. These two rivers join just prior to entering Massachusetts Bay. The remaining areas are drained by small streams; many of these empty directly into the bay.

The hydraulics of the North and South Rivers are difficult to analyze or model. The flat topography results in tidal water affecting both rivers for many miles inland. In the upper drainages cranberry bogs, with their stream diversions, storage ponds, and delivery systems modify the natural surface water flow patterns. This makes it very difficult to determine where and how much water will flow from or through these areas. Flow patterns and volumes are dependent upon how the diversions and control structures are set and the existing water levels in the bogs and ponds. Streamflows vary greatly throughout the year even though monthly precipitation is quite uniform. Flows are high in the winter and early spring when the ground is frozen and evapotranspiration is low and low during the summer months or growing season when evapotranspiration is high. Small streams and those being used for bog irrigation may be intermittent during the growing season. Low flow information for stream gages in the Basin is presented in Table I-4. The average monthly streamflow and evapotranspiration are shown in Figures I-4 and I-5.

Table I-4

Low Flow Streamgage Data

USGS Gage Number	Location	Drainage Area (sq. miles)	7-day, 2-year flow		7-day, 10-year flow	
			(million gal. per day)	(cubic ft. per second)	(million gal. per day)	(cubic ft. per second)
01105730	Indian Head River at Hanover 1/	30.3	2.3	3.5	1.0	1.5
01105810	Third Herring Brook at Hanover	9.85	0.26	0.40	0	0
01105680	Cushing Brook at West Hanover 2/	4.28	0.13	0.20	0	0
01105700	Indian Head Brook near Hanson	4.39	0.32	0.50	0.13	0.20
01105848	Furnace Brook at School St. near Marshfield	0.94	0.01	0.02	0	0
01105845	South River at Marshfield	7.5	1.3	2.0	1.0	1.5
01105820	Second Herring Brook at Norwell	3.22	0.13	0.20	0	0
01105770	Herring Brook at Pembroke	5.48	0.65	1.0	0.39	0.60
01105805	Pudding Brook at North Pembroke 1/	4.53	0.32	0.50	0.19	0.30
01105690	French Stream near Rockland 2/	4.99	0.71	1.1	0.32	0.50
01105830	First Herring Brook near Scituate Ctr.	1.72	0.01	0.02	0	0

1/ Some regulation by pond(s) above gage.
2/ Flow affected by diversion above gage.

Data source: Water Resources of the Coastal Drainage Basins of Southeastern Massachusetts, Weir River, Hingham, to Jones River, Kingston, by John R. Williams and Gary D. Tasker; Hydrologic Investigations Atlas HA-504 (sheet 1 of 2); U.S. Geological Survey.

Figure I-4

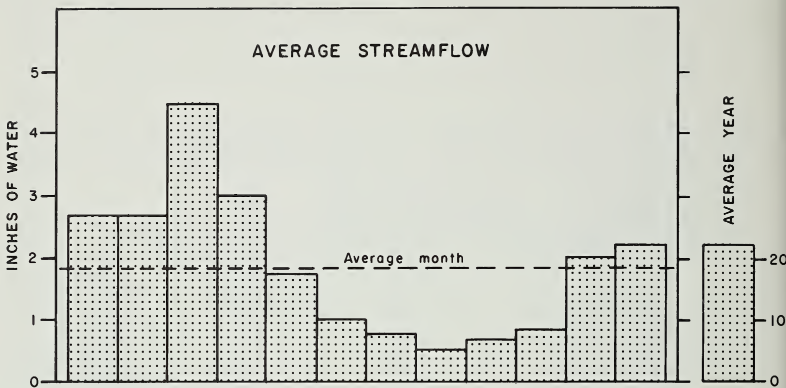
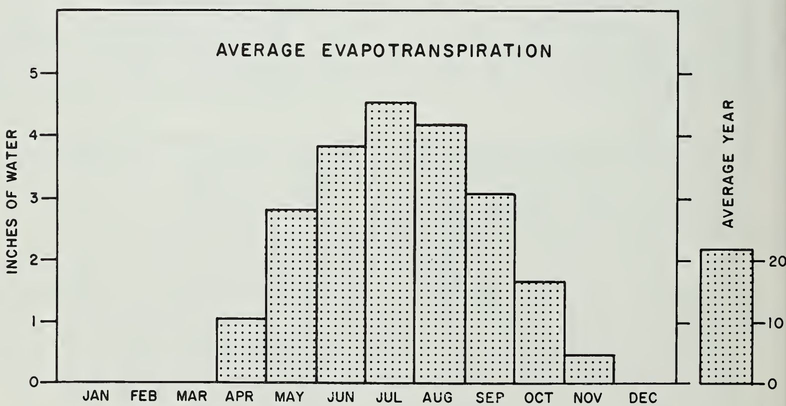


Figure I-5



These data are from the USGS Hydrologic Investigations Atlas HA-504, 1974, Water Resources of the Coastal Drainage Basins of Southeastern Massachusetts, Weire River, Hingham, to Jones River, Kingston, by John R. Williams and Gary D. Tasker.

b. Groundwater

Communities within the North and South Rivers Basin are heavily dependent on groundwater for water supply. Of the eight communities, Duxbury, Hanover, Marshfield, Norwell, and Pembroke rely solely on groundwater supply. Scituate and Rockland rely upon groundwater to some extent. Hanson is entirely supplied by surface water but is developing a well.

Appendix IV of this report contains several maps dealing with the groundwater resources of the Basin. The Surficial Geologic Materials Map shows glacially deposited materials based on their potential for infiltration. The groundwaters map shows geohydrologic boundaries of the aquifers. For this report and simplicity of analysis, surface watershed divides and groundwater divides were assumed to be coincident. A well watersheds map is included to show that surface area which contributes to recharge of each municipal well.

The Recharge Areas Map, based on permeabilities of soils units, can be used to locate those areas which direct the most precipitation to groundwater supplies. The potential groundwater hazards map shows location of saltpiles, landfills, and locations of underground storage of flammable liquids.

All groundwater maps for this report are for planning purposes only. Where boundaries are shown, they have been shown for use in compiling quantities for broad scale planning. Detailed hydrogeologic studies are required to determine well cones of depression, aquifer boundaries, and other geohydrologic characteristics of aquifers. Such detailed studies are beyond the scope and purpose of this report.

c. Water Diversions

Analysis of the water resources in the North and South Rivers Basin is somewhat complicated by diversions of water to and from the Basin. Figure I-6 illustrates the diversions in a schematic manner.

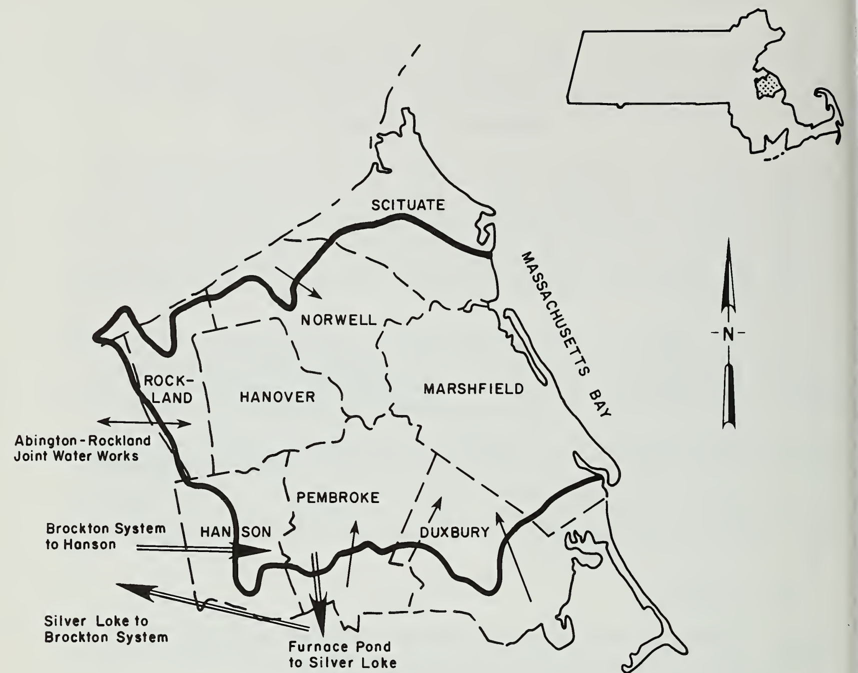
The Brockton Water Commission has long utilized Silver Lake in Pembroke as a municipal water supply source. To augment the safe yield of Silver Lake, diversions are made into the lake from Monponsett Pond in Halifax and Furnace Pond in Pembroke. Hanson obtains its municipal water from the Brockton Water Commission.

The Abington & Rockland Joint Water Works supplies water to Rockland residents primarily from sources outside the Basin in Abington.

In addition to the diversions described above, Pembroke, Duxbury, and Norwell have developed sources of supply within their local boundaries yet outside the North and South Rivers Basin.

d. Recreation Developments

Water-based recreation developments are dependent upon good water quality. Class B water is required by state health standards for water contact sports (such as swimming) and is desirable for fishing, boating, and other water-associated activities. Recreation developments supporting water-based



LEGEND

- RIVER BASIN BOUNDARY
- TOWN LINE
- INTERBASIN TRANSFER
- INTERBASIN TRANSFER WITHIN A MUNICIPALITY

Figure I-6

INTERBASIN WATER TRANSFERS
NORTH-SOUTH RIVERS BASIN
MASSACHUSETTS RIVER BASIN PLANNING PROGRAM
1982

activities in the North and South Rivers system are fortunate to have Class A water quality for all but several upper tributaries in the major channels.

Most recreation developments are associated with natural environment or conservation areas, offering primarily passive or non-intensive activities. There is also a fair amount of historical and cultural areas along rivers and streams representing old mill sites, shipyards, and other locally important sites that are incorporated in recreational areas. Numerous private docks, landings, and access points support additional use.

The majority of the water-based recreation along the North River is associated with marinas for access and services for pleasure craft. With the proximity of the ocean and miles of beaches available, most swimming occurs along the shoreline. Freshwater swimming is accommodated primarily with municipally-owned indoor swimming pools. A significant number of private swimming pools exist in Duxbury, Marshfield, and Scituate.

The town of Scituate is installing a water-based recreation development at the Driftway on the Herring River with assistance from the Soil Conservation Service under the auspices of the Pilgrim Resource Conservation and Development Area. The project includes a fishing pier, hiking trails, an observation tower, picnic sites and pavilion, and a boat ramp.

Population

The River Basin experienced a doubling of population in the 20-year period between 1940-1960 and again between 1960-1980. A number of factors contributed to this extraordinary growth. Industrial and commercial growth in Boston and adjacent areas provided regional employment opportunities. Given the relatively low transportation costs of that era, many people chose to live in towns considerable distances from their place of employment. The towns of the North and South Rivers Basin offered attractive natural amenities and a residential setting unaffected by industrial and commercial development. Improvements in major highways connecting Boston and Cape Cod contributed to this action. Some of the population growth was explained by noting the general demographic trends of the post World War II period.

The Basin is expected to show continued population growth through the year 2020; however rates of growth will not be nearly as great as in the past. For example, for the period 1980-2000 the projected growth rate is 18 percent or less than 1 percent per year.

The following table presents population data and projections for each town within the North and South Rivers Basin:

Table I-5

North-South Rivers Basin

Population Data & Projections

Town	YEAR									
	1940	1950	1960	1970	1975	1980	1990	2000	2010	2020
Duxbury	2,399	3,167	4,727	7,636	10,600	11,807	14,400	14,600	15,100	15,500
Hanover	2,875	3,389	5,923	10,107	10,533	11,358	12,900	13,200	13,300	13,300
Hanson	2,570	3,264	4,370	7,148	8,331	8,617	10,400	10,600	10,700	10,700
Marshfield	2,419	3,267	6,748	15,223	19,450	20,126	23,700	24,300	24,500	24,500
Norwell	1,871	2,515	5,207	7,796	8,999	9,182	11,100	11,600	11,700	11,700
Pembroke	1,718	2,579	4,919	11,193	12,374	13,487	16,500	17,200	17,400	17,500
Rockland	8,087	8,960	13,119	15,674	17,028	15,695	15,700	15,700	15,700	15,700
Scituate	4,130	5,993	11,214	16,973	17,829	17,317	17,300	17,300	17,300	17,300
8 Town Total	26,028	33,134	56,227	91,750	105,144	107,589	122,000	124,500	125,700	126,200

Sources:

Historical Population Data - Duxbury, Hanover, Marshfield, Norwell, Rockland, Scituate, Areawide Waste Treatment Management Plan for the Metropolitan Boston Area, Part I, Volume II; Metropolitan Area Planning Council, Boston, 1978.

Historical Population Data - Hanson, Pembroke, Water Supply & Water Use in the OCPC 208 Area, Old Colony Planning Council, Brockton, MA, 1975.

1980 Preliminary Census Data.

Projections - Interim projections for 1990, 2000, and 2010 for all communities except Hanson developed by Metropolitan Area Planning Council, January 1982.

Hanson 1990 projection developed by Massachusetts Division of Water Resources.

Projections for 2020 developed as extrapolations of 1990-2010 projections.

Table I-6

Land Use Data

	LAND USE					
Town & Date	Urban (acres)	Agriculture 3/ (acres)	Recreation (acres)	Open (acres)	Forest, Wetland, & Water 2/ (acres)	Total (acres)
Duxbury						
1951	1,088	2,038	1/	678	11,650	15,454
1971	3,273	820	452	679	10,230	15,454
1980	4,305	687	455	446	9,561	15,454
Hanover						
1951	776	1,327	1/	376	7,499	9,978
1971	2,820	270	40	464	6,384	9,978
1980	3,677	159	99	153	5,890	9,978
Hanson						
1951	524	1,690	1/	98	7,659	9,971
1971	1,977	797	68	317	6,812	9,971
1980	2,126	730	141	172	6,802	9,971
Marshfield						
1951	1,474	2,181	1/	675	14,348	18,678
1971	4,146	604	359	602	12,967	18,678
1980	5,759	236	288	243	12,152	18,678
Norwell						
1951	173	1,300	1/	447	11,213	13,133
1971	2,565	357	14	322	9,875	13,133
1980	3,371	326	16	132	9,288	13,133
Pembroke						
1951	281	1,862	1/	358	12,783	15,284
1971	2,965	666	183	461	11,009	15,284
1980	4,088	634	153	424	9,985	15,284
Rockland						
1951	1,135	780	1/	287	4,219	6,421
1971	2,055	58	97	456	3,755	6,421
1980	2,417	49	157	372	3,426	6,421
Scituate						
1951	1,516	1,318	1/	591	7,856	11,281
1971	3,737	244	424	252	6,624	11,281
1980	4,674	144	169	104	6,190	11,281

Sources: 1951 & 1971 data from MacConnel, William P., "Remote Sensing 20 Years of Change in Plymouth County, Massachusetts, 1951-1971", Cooperative Extension Service, 1973.

1980 data from updated land use map prepared by Soil Conservation Service from soil maps latest USGS topographic quadrangles, town Natural Resources Planning Program maps, and updated town maps.

Notes: 1/ Recreation land was not mapped as a separate category in 1951.

2/ Forest, wetland, and water categories were aggregated into one reporting category to minimize the effect of procedural and definitional differences between sources of land use data.

3/ Agricultural land figures do not include cranberry bogs. These are included in the Forest, Wetland, & Water category since the 1951 and 1971 MacConnel data did not differentiate between producing and non-producing bogs. See Table I-8 for current figures on producing cranberry bogs.

6. Use of Resource Base

a. Land Use

Table I-6 presents land use data for the eight Basin communities for three years spanning a three decade timeframe. Some trends in land use changes are shown in Figure I-7.

The data show some general trends that are a subject of concern throughout Massachusetts and, in fact, throughout the nation. During the period 1951-1980, urban land use increased in each of the Basin towns. At the same time, land in agricultural and forest, wetlands, and water bodies showed a decline. The increase in urban land area was primarily attributable to an increase in town population and partially due to a trend toward more urban land per capita. The increase in per capita urban use of land in the region was caused by increased public land use (highways, regional shopping centers) and low-density suburban-type development.

b. Water Use

Table I-7 presents a summary of water resource use by the Basin communities. Total average daily demand in the nine towns (including Abington) is about 13.4 million gallons. In an average year, the Basin residents call upon their municipal water systems to deliver over 4.9 billion gallons of potable water.

Table I-7

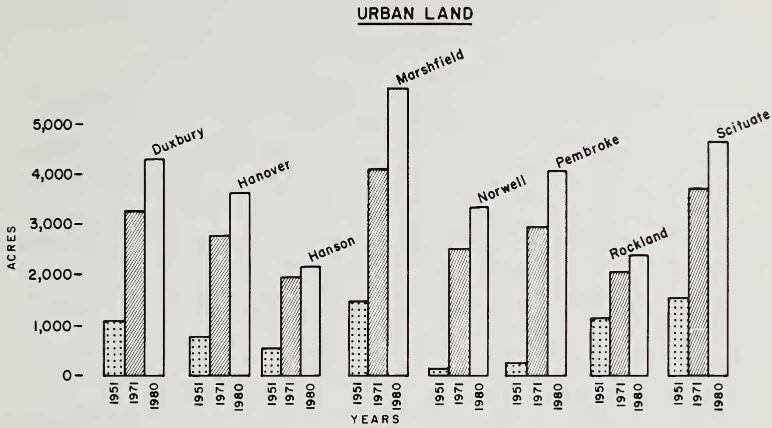
Water Use In Basin Communities, 1980

Town	Yearly Use (MG)
Duxbury	410
Hanover	450
Hanson	330
Marshfield	1,160
Norwell	370
Pembroke	410
Rockland 1/	990
Scituate	780

1/ Includes Abington served by Abington-Rockland Joint Water Board

Individuals desiring more detailed data concerning municipal supply in the North and South Rivers Basin are referred to Appendix IV.

Figure I-7


URBAN LAND
5,000
4,000
3,000
2,000
1,000
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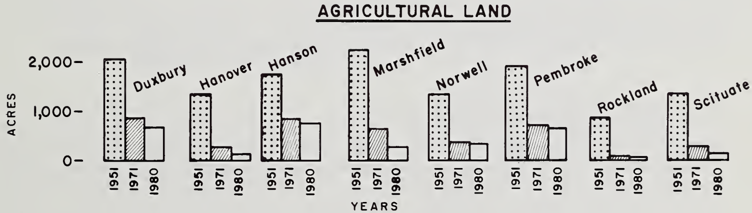
ACRES
Duxbury
Hanover
Hanson
Marshfield
Norwell
Pembroke
Rockland
Scituate
1951
1971
1980
YEARS


AGRICULTURAL LAND
2,000
1,000
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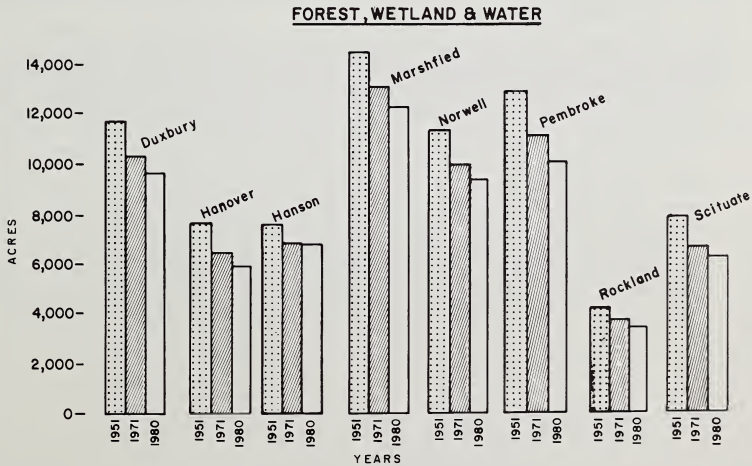
ACRES
Duxbury
Hanover
Hanson
Marshfield
Norwell
Pembroke
Rockland
Scituate
1951
1971
1980
YEARS


FOREST, WETLAND & WATER
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
ACRES
Duxbury
Hanover
Hanson
Marshfied
Norwell
Pembroke
Rockland
Scituate
1951
1971
1980
YEARS

In addition to the municipal water use, the production of cranberries is a notable use of the water resource. Table I-8 presents some pertinent data on cranberry bogs in the Basin.

Table I-8

Cranberry Bog Data

Town	Acres of Productive Bogs (Acres)	Acres of Bog w/Sprinkler Systems	Estimated Average Annual Water Use (Acre Feet) 1/
Duxbury	267	255	1,400
Hanover			
Hanson	187	187	930
Marshfield	96	37	780
Norwell	13	13	70
Pembroke	284	262	1,520
Rockland			
Scituate	23	23	120

1/ Water use computed assuming 60 inches of water required per year in sprinklered bogs and 120 inches required in non-sprinklered bogs.

c. Agricultural Production

Plymouth County is important to state and national agriculture. Nationally it ranks as one of the leading producers of cranberries with production of nearly one million barrels per year. In terms of the state's agricultural product, Plymouth County is also an important dairy area. In addition, a variety of fruit, vegetable, and greenhouse crops are produced for local consumption.

The 1978 Census of Agriculture lists 589 farms and a total farm area of 82,924 acres in Plymouth County. The average farm size is 141 acres which is more than 20 percent larger than the state average of 115 acres. Table I-9 gives the number of various livestock and acreage for major crops.

Table I-9

Agricultural Production Data
Plymouth County

Livestock	No. Farms	No. Livestock
Cattle	105	4,783
Hogs, Pigs	60	5,649
Sheep and Lambs	37	476
Horses or Ponies	59	431
Chickens	54	25,165
Turkeys	10	680
Goats	13	172
Crops	**No. Farms**	**Acres**
Berries	330	9,042
Hay	137	4,656
Corn	39	3,496
Alfalfa	53	1,194
Vegetables	67	854

Source: 1978 Census of Agriculture. U.S. Department of Commerce, Bureau of the Census.

The North and South Rivers Basin has approximately 3800 acres of agricultural land which is 4 percent of total land use. A survey of cranberry bogs identified 870 acres of productive bogs and approximately 80 acres of non-productive bogs in the Basin. Given an average production rate of 80 barrels per acre, the total cranberry production for the Basin is estimated to be 69,700 barrels annually. (Barrel = 100 pounds). Basin estimates for other crops are not available.

d. Industrial Influence

In the early 1970's the Old Colony Planning Council conducted an Economic Base Study for the purpose of presenting information and recommendations which might be used to foster economic growth and development in the region. Specific recommendations included creation of a regional economic development and financing corporation to sponsor and carry out an industrial development program in the region. A preliminary examination was made of firms with a record of growth and those firms in key industries The results indicate that most firms having potential for growth or expansion are taking steps to assure development. While planners are optimistic about future industrial growth, the level of development is not expected to significantly alter the primarily residential land use characteristics of the Basin. The following table shows employment for various types of activities for 1980.

Table I-10

Employment in the North-South Basin

Town	Total Annual Payroll in 000's	Average Annual Wage	# of Estab-ment	Average Annual Employment									
				Total Employ-ment	Govern-ment	Agric. Forestry Fisheries	Min-ing	Contract Const'n.	Manu-factur-ing	Trans. Comm. Util.	Whole/ Retail Trade	Finance Insur. R.E.	Ser-vice
Scituate	29,752.7	10,729	256	2,767	702	15	0	91	282	42	961	100	579
Marshfield	30,973.7	10,549	306	2,937	865	C	0	169	130	128	1,156	133	337
Hanson	12,450	10,077	110	1,231	469	41	0	52	141	0	373	67	84
Duxbury	17,825.7	12,242	200	1,453	528	33	0	126	89	61	343	40	233
Pembroke	11,875.1	9,120	166	1,301	141	0	0	81	153	9	628	54	224
Hanover	51,716.3	9,135	271	5,657	652	32	0	112	947	69	3,304	70	471
Rockland	58,774.5	11,750	251	5,006	580	13	0	138	1,798	58	1,306	392	713
Norwell	25,687.1	11,697	184	2,196	389	0	0	121	125	0	826	0	520

C = Confidential information because of small number of employers in category.

7. Unique or Special Features

a. Cultural, Historical, and Archeological Features

The North and South Rivers area abounds with history and many significant cultural, historical, and archeological features may be found. Points of interest are abundant along the main stems and primary tributaries of the North and South Rivers. Historically, the rivers served primarily as transportation routes and were later used to provide water power for mills and factories and areas for shipbuilding and fishing.

Archeological sites are also associated with the river system as evidenced by clamshell mounds, campsites, fish weirs, and other relics. It is estimated that 10,000 Indians, descendants of the Algonquin Nation, once lived in the confines of the North and South Rivers area. Early settlers used the saltmarsh meadows for thatch, insulation, hay and forage for animals. Ferries and bridges were constructed as settlement and commerce expanded. Sawmills, gristmills, shingle mills, box mills, iron works, and tack factories flourished for a period of time. The North River produced over a thousand ships with almost every bend of the river having a shipyard or landing. Today the rivers are primarily used for recreation and aesthetic enjoyment. A list of cultural and historical features obtained from Town Historical Commissions is provided in Table I-11.

Table I-11

Cultural, Historical, and Archeological Features

DUXBURY

1. Gershom Bradford House. Built in 1808 by Captain Gershom Bradford. Interesting hand-wrought moulding in hall.
2. Gamaliel Bradford House. Built in 1807 by Captain Gamaliel Bradford on land inherited by his father. He was a prosperous seafaring man.
3. King Caesar House. Built in 1808 by Ezra Weston II. He was a member of a leading family shipping firm.
4. Alexander Standish House. Built in 1666 by the son of Myles Standish. This simple gambrel cottage was passed down in the family for nearly 100 years.
5. First Parish Church. Built in 1840 by Duxbury shipbuilders. Paul Revere Bell hangs in steeple.
6. John Alden House. Built by John and his 3rd son in 1653. He was the last survivor of the signers of the Mayflower Compact.
7. (High concentration of other, less important, historical sites.)

HANOVER

1. Luddam's Ford
2. North River
3. Fireworks - Factory Pond
4. Hanover/Hanson Dam
5. Ellis Field
6. St. Colletta's
7. Portiuncula Chapel
8. North River - Stone Bridge
9. Hanover Mall
10. St. Mary's Church
11. Hackett's Pond
12. Tindale Bog
13. Hanover Four Corners
14. First Congregational Church
15. Transfer Station
16. Cervellis Corn Field
17. Assinippi
18. West Hanover
19. Sylvester Field

HANOVER (Cont'd)

20. Town Hall - Police Station
21. Stetson House
22. Forge Pond
23. Cemetery
24. Briggs Stable
25. Lutheran Church
26. St. Andrew's Church
27. Curtis School
28. Salmond School
29. Clark Cranberry Bog - Cons. Comm.
30. Absalom's Rock
31. Center Hanover Fire Station
32. John Curtis Library
33. Bridge @ Washington Street
34. Mill Street Bridge
35. Poor's Pond
36. Water Treatment Plant - DPW
37. Star Land
38. Tedeschi Shopping Center (Stop & Shop site)
39. Garden Craft
40. Assinippi General Store
41. Post Office
42. Baptist Church
43. Riverside Drive
44. Washington Street View to North River
45. High School
46. Sylvester School
47. Center School
48. West Hanover Fire Station
49. South Hanover Fire Station
50. King Street Fire Station

HANSON

1. Wampatuck Hall. Main Street. Built in 1893 it is now owned by the Masons. Historic Building.
2. Luther Keene House. Main Street. It was built in 1790. Historic Building.
3. Cranberry Canning Plant. Main Street. Built in 1912 it is still used as the Ocean Spray Plant. Historic Building.
4. Ebenezer Keene House. High and Main Streets. It was built in 1821. Historic Building.
5. Grand Army Hall. High Street. It was built in 1893. Historic Building.
6. Hannible Hamlin House. Holmes Street. It was built in 1752, and was owned by Hannible Hamlin who was Lincoln's Vice-President. Historic Building.
7. Vigneault House. West Washington Street. It was built around 1704. Historic Building.
8. Gad Soper House. Spring Street. Built in 1810, it was at one time used as an inn. Historic Building.
9. Drew Homestead. Spring Street. It was built in 1801. Historic Building.
10. Cornelius Cobb House. West Washington Street. It was built in 1803. Historic Building.
11. Elijah Cushing House. Liberty and East Washington Street. It was built in 1724. Historic Building.
12. Nahum Stetson House. 305 King Street. It was built around 1700. Historic Building.
13. Thomas Hall. West Washington Street. It was built in 1884. Historic Building.
14. Gad Hitchcock House. High Street and County Road. It was built about 1722. Historic Building.
15. Town Hall. Liberty Street. This house is of pre-revolutionary origin. Historic Building.
16. Chapman House. 499 State Street. This house is of pre-revolutionary origin. Historic Building.

Table I-11

Cultural, Historical, and Archeological Features

MARSHFIELD

1. Tea Rock Hill. 851 Moraine Street.
2. Site of Old South School. 1822-1857. Corner of Webster and Parsonage Streets. Original school was established in 1645.
3. Winslow Cemetery. Winslow Cemetery Road, off Webster Street.
4. Site of Daniel Webster's Home. Webster Street. 1832-1852.
5. Historic Winslow House. Webster and Careswell Street. 1699.
6. Office of Daniel Webster. Webster and Careswell Streets.
7. Careswell. Off Careswell Street. Site of original Winslow house. Built about 1636-1637.
8. Early Canal. Canal Street. 1633.
9. Green Harbor Dike. 1871-1872.
10. Site of Fessenden Tower - Wireless Experimental Station. Blackman's Point, Brant Rock.
11. Site of Life Saving Station. Brant Rock.
12. Old Mouth of the North and South Rivers.
13. Pilgrim Trail. Ocean Street (the Neck Road or Marshfield Neck).
14. First Congregational Church. Ocean Street. 1838.
15. The Common or Training Green. Opposite the First Congregational Church. Granted in 1663.
16. Store of Proctor Bourne. 2000 Ocean Street.
17. Site of Peregrine White House. Off South River Street. "First white native in New England."
18. Site of White's Ferry. Ferry and Sea Streets. Ferry across North River.
19. Former Unitarian Church. Main Street, Marshfield Hills.
20. Roger's Store. Built in 1823 by Luther Rogers.
21. Little's Bridge. Site of old Indian ferry in 1825.
22. Union Bridge. At end of Union Street. Toll bridge in 1800.
23. Gravelly Beach. Site of one of the Rogers shipyards.
24. Hatch Mill. Union Street, Two Mile, Marshfield. Operated for 200 years.
25. The Two Mile. Strip of land along North River.
26. Memorial Park. Honors those who lost their lives in World War II.
27. Marshfield Fair Grounds. Main Street and South River Street.
28. The Hearse House. Main Street. Held first town meetings.

NORWELL

1. Bryant Cushing House. Built in 1698 by Deacon Thomas Bryant. House contains many noteworthy architectural features.

PEMBROKE

1. Oldham Pond Site. Off Oldham Street. Archaeological Site.
2. Barzella Bryant House. Plymouth Street. 1700's. Historic Building.
3. Mayflower Grove. School Street. A recreation area from 1901-1940 with bowling, dancing, boating, and a theater. It was destroyed by a hurricane in 1938. Historic site.
4. Furnace Pond Site. Off Mattakeesett Street. Archaeological Site.
5. No-Bottom Pond Site. Off Wampatuck Street. Archaeological Site.
6. Below Furnace Pond. Archaeological Site.
7. Henry Josselyn House. West Elm Street. Historic Building.
8. William Oldham House. West Elm Street. Historic Building.
9. Mattakeeset Street Site. Archaeological Site.
10. Nathaniel Perry House. Mattakeesett Street. 1700. Historic Building.
11. Issac Little House. Little's Avenue. Historic Building.
12. Henry Josselyn House. Mattakeesett Street. Historic Building. 1700.
13. Thatcher Magoun House. Washington Street. 1783. Historic Building.
14. Friends Meeting House. Washington Street. It was built in 1706 by some of the first families who settled in Pembroke. The building is believed to be one of the oldest Quaker Meeting Houses in New England. Historic Building.
15. Thatcher Magoun House. Washington Street. 1695. Historic Building.
16. Adah Hall House. Barker Street. 1685. Historic Building.
17. Peter Salmond House. Barker Street. 1700. Historic Building.
18. David Orchard Site. Archaeological Site.
19. Luther Briggs House. Brick Kiln Lane. 1700. Historic Building.
20. Collamore Estate. Washington Street. 1711. Historic Building.
21. Squire Keene Mansion. Barker Street. 1745. Historic Building.
22. Captain John Turner House. Washington Street. 1730. Historic Building.
23. Ichabod Loring House. Barker Street. 1770. Historic Building.
24. Recompense Magoun House. High Street. 1719. Historic Building.
25. Nathaniel Loring House. High Street. 1702. Historic Building.
26. Thomas Sampson House. Forest Street. 1700. Historic Building.

Table I-11

Cultural, Historical, and Archeological Features

ROCKLAND

1. (Small Concentration of Historical Sites)

SCITUATE

1. Cudworth House, Barn and Cattle Pond.
2. Lawson Tower. A gift to the town in 1902 from Thomas W. Lawson.
3. Stockbridge Mill - 1640.
4. The Old Oaken Bucket - 1675.
5. Belle House - 1742.
6. Cushing Memorial State Park - Site of grave of Justice Cushing.
7. North River Bridge - Site of first ferry established in 1637 by William Vassall.
8. Mann Farmhouse and Historical Museum.
9. Men of Kent Cemetery - Site of the first chuch built in 1636.
10. Satuit Brook.
11. The Bates House - Built before 1795.
12. Williams-Barker House (Barker Tavern) - 1634.
13. The Scituate Lighthouse - 1811.
14. Early Boundary Line - Originally established in 1640.
15. Mordecai Lincoln Mill and Homestead - 1691-1692.

b. Vertebrates of the North-South Rivers Basin Area

Dense human populations invariably have resulted in significant land use changes from that found in the pre-colonization landscape. The forest primeval was first cleared for open land agricultural endeavors; over time much agricultural land then either reverted back to forest or was gradually converted to urban and suburban uses. Forest is gradually being converted to single family dwelling lots, roads, and other public needs. Despite the major land use changes which have occurred in this Basin since colonization began, there are still substantial fish and wildlife resources available. The black bear, timber wolf, bobcat, and wild turkey no longer live in the Basin. These and other species which require large expanses of primarily forest land with little or no human population have been extirpated as a consequence of loss of suitable habitat. Other species which have large home ranges such as whitetail deer, river otter, gray fox, and red fox are uncommon and have a tenuous future in the Basin.

Species of fish which require good quality water have been adversely affected by land use changes and human cultural influences. Brook trout, once common in the small tibutaries of the Basin are now nearly non-existent. The availability of trout for fishing recreation is now dependent on annual stocking of hatchery-reared fish by the Massachusetts Division of Fisheries and Wildlife. Pollutants including sediment, chemical and organic loading, and physical changes to the streams, have degraded the character and water chemistry of many former trout streams to the extent that they no longer support self-sustaining trout populations.

Vertebrate wildlife species which have small home ranges or are migratory and whose nesting requirements are available continue to thrive throughout the Basin. Land use changes have greatly reduced available habitat for some species and increased available habitat for others. The following tables list the five classes of vertebrate species in the Basin and the species found within each class. Relative abundance and typical habitat for each species is also presented. Much of the information for this table was taken from An Inventory of Massachusetts Fish and Wildlife (Vertebrate) Resources, developed by Paul S. Mugford of the Massachusetts Division of Fisheries and Wildlife in 1975. Additional information is from Massachusetts Species for Special Consideration, Fauna of Massachusetts Series No. 5, 1979, developed by the Massachusetts Division of Fisheries and Wildlife.

In the tables certain species are designated as threatened, endangered, state rare, state local, and peripheral. These designations are defined as follows:

Endangered species - Any species which is in danger of extinction through all or a significant portion of its range in the world. These species are listed under provision of the federal Endangered Species Act of 1973 (Federal Register 41(208): 47180-47198).

Threatened species - Any species which is likely to become endangered within the foreseeable future through all or a significant portion of its range. These species are also listed under provisions of the federal Endangered Species Act of 1973.

State rare - Long established breeding or wintering species quantitatively documented to be declining, facing extirpation from the Commonwealth, and considered likely to disappear without special action.

State local - Long established breeding or wintering species in the Commonwealth that are restricted to very limited areas. A few species, which are widespread but nowhere frequent, are also included.

Peripheral breeding species - These are species which reach the limits of the normal breeding distribution in Massachusetts. The possibility exists that some of these species may be undergoing cyclic range fluctuations. Management potential may be limited for these species since their ultimate fate is controlled by natural events.

Table I-12

BIRDS FOUND IN THE NORTH-SOUTH RIVERS BASIN AREA

Bird	Relative Abundance	Typical Habitat
American bittern* 3/	Common	Fresh and salt water marshes
Least bittern 3/	Rare	Marshes, especially those with cattails
Red-winged blackbird*	Abundant	Wet meadows, shrub swamps, fresh water marshes
Rusty blackbird 4/	Common	Wooded swamps, shrub swamps, marshes, wet meadows, hay fields
Eastern bluebird*	Rare	Woodland edges, orchards, agricultural lands
Boblink*	Uncommom	Marshes, wet meadows, idle agricultural land
Bobwhite*	Uncommon	Shrub thicket, idle agricultural land
Brant	Uncommon - coastal	Ocean bays, coves, and large estuaries
Bufflehead	Common - coastal	Undeveloped lakes and rivers, marshes, bays
Indigo bunting*	Uncommon	Dry shrub thicket, woodland edges
Snow bunting	Common to uncommon	Salt marsh, tidal flats, ocean beach, fields
Canvasback	Uncommon - coastal	Large rivers, bays, lakes, and large ponds
Cardinal*	Common	Edge of brush woodland, suburban areas
Gray catbird*	Common	Shrub thickets, hedgerows, shrubby stream sides
Yellow-breasted chat	Uncommon	Dry shrub thickets
Black-capped chickadee*	Common	Woodland, woodland edges, suburban areas
American coot*	Uncommon	Freshwater marshes, ponds, slow rivers, estuaries
Double-crested cormorant*	Uncommon - coastal	Large rivers and lakes, ocean bays, open ocean
Great cormorant	Rare - coastal	Rocky ocean shore, bays and open areas

Bird	Relative Abundance	Typical Habitat
Brown-headed cowbird*	Common	Hay fields, woodland edges, open woodland
Brown creeper*	Uncommon	Woodland swamps, wooded streamlets, woodlands
Red crossbill	Rare	Coniferous woodland
White-winged crossbill	Rare	Coniferous woodland
Common crow*	Common	Woodland, agricultural areas, parks, coast
Fish crow*	Rare	Coast, estuarine waters
Black-billed cuckoo*	Uncommon	Woodland
Yellow-billed cuckoo*	Uncommon	Shrub thicket, orchards, wooded streamsides
Dickcissel	Common to uncommon	Hay fields and pastures
Mourning dove*	Common	Open grown conifers, agricultural land, hedgerows, suburban land
Rock dove*	Abundant	Cities, parks, large bridges, barns
Dovekie	Uncommon - off-shore	Open ocean and coast
Long-billed dowitcher	Uncommon - coastal	Fresh and salt marshes, tidal flats, ocean beach
Short-billed dowitcher	Common - coastal	Fresh and salt marshes, tidal flats, ocean beach
Black duck*	Common	Shrub swamps, fresh or salt water marshes, bays
Harlequin duck	Uncommon to rare	Rocky ocean front, rocky breakwaters
Ring-necked duck 4/	Common	Ponds, undeveloped lakes, and slow rivers
Ruddy duck* 4/	Common - coastal, rare - inland	Ponds, lakes, slow rivers, bays
Wood duck*	Common to uncommon	Fresh water marshes, shrub swamps, wooded swamps, slow streams
Dunlin	Common	Ocean beaches, shore line, and mud flats

Table I-12

BIRDS FOUND IN THE NORTH-SOUTH RIVERS BASIN AREA

Bird	Relative Abundance	Typical Habitat
Bald eagle	Endangered 1/	Near large rivers, lakes, or ocean
Golden eagle	Rare	Forests, mountains
Cattle egret*	Rare	Wet meadows
Great egret* 3/	Uncommon to rare	Rivers, ponds, fresh or salt marshes, wooded swamps
Snowy egret	Uncommon to rare	Wet meadows, fresh or salt water marshes, mud flats, any shallow water
Common eider	Common - coastal	Rocky seacoast, offshore ocean islands
King eider	Uncommon to rare	Rocky seacoast, offshore reefs and shoals
Peregrine falcon	Endangered 1/	Cliffs, high buildings, large dead trees
House finch*	Uncommon	Agricultural areas, suburbs
Purple finch*	Uncommon	Coniferous woodland, woodland edges, often in suburbs
Yellow-shafted flicker*	Common	Deciduous woodland, woodland edges, suburbs
Alder flycatcher	Common to uncommon	Shrub swamp, shrubby streamsides, suburbs, orchards
Great-crested flycatcher*	Common to uncommon	Woodland, woodland edges, orchards
Least flycatcher*	Common	Orchards, shrubby streamsides
Willow flycatcher*	Uncommon to rare	Bogs, shrubby streamsides, conifer bordered streamsides
Gadwall*	Uncommon	Fresh marshes, ponds and undeveloped lakes, large slow rivers
Common galinule*	Uncommon	Freshwater marshes
Gannet	Common - coastal	Open ocean and ocean bays
Blue-gray gnatcatcher*	Uncommon - coastal	Wooded swamp, shrub thickets
Marbled godwit	Rare - coastal	Ocean shore, mud flats, salt marshes, wet meadows
Hudsonian godwit	Rare - coastal	Ocean shore, mud flats
Barrow's goldeneye	Uncommon - coastal	Lakes, ponds, ocean bays, ocean
Common goldeneye	Common - coastal	Lakes, large rivers, ocean bays, ocean
American goldfinch*	Common	Idle agricultural land, woodland edges, suburban areas
Blue goose	Rare	Bays, marshes, especially coastal areas
Canada goose*	Common	Undeveloped banks of large rivers, lakes, ponds, bays
Snow goose	Rare	Large rivers and ponds, lakes, bays, marshes, fields
Goshawk*	Uncommon to rare	Forests, especially coniferous
Common crackle*	Abundant	Agricultural land, woodland edges, suburban areas
Horned grebe	Uncommon	Fresh water lakes and ponds, estuaries and bays
Pied-billed grebe*	Common	Fresh water ponds and marshes, large rivers and estuaries
Red-necked grebe	Uncommon	Fresh water ponds, large rivers and estuaries
Evening grosbeak	Common to uncommon	Coniferous woodland, woodland edges
Pine grosbeak	Rare	Coniferous woodland, woodland edges
Ruffed grouse*	Uncommon	Brushy woodland
Black guillemot	Uncommon - coastal	Rocky islands, open ocean
Black-headed gull	Rare	Bays, estuaries, harbors
Bonaparte's gull	Common	Ocean coast, large rivers, estuaries
Glaucous gull	Uncommon	Ocean coast, open ocean, dumps
Great black-backed gull*	Common	Coastal ponds and lakes, ocean coast
Herring gull*	Abundant	Coastal ponds and lakes, ocean coast, and dumps

Table I-12

BIRDS FOUND IN THE NORTH-SOUTH RIVERS BASIN AREA

Bird	Relative Abundance	Typical Habitat
Iceland gull	Uncommon	Coastal lakes and rivers, ocean coast, and dumps
Laughing gull* 3/	Abundant	Ocean coast, estuaries, islands, large rivers, salt marsh
Little gull	Rare	Ocean coast, estuaries
Ring-billed gull	Common	Ocean coast, coastal lakes and ponds, dumps
Broad-winged hawk*	Common to uncommon	Deciduous woodlands
Cooper's hawk*	Uncommon	Forests and forest edges
Marsh hawk* 3/	Uncommon	Wet meadows, fresh or salt marshes
Pigeon hawk	Uncommon to rare	Forests, open land in winter
Red-shouldered hawk*	Uncommon	Moist woodland and river bottoms
Red-tailed hawk*	Common	Upland woodland, marshes and fields
Rough-legged hawk	Rare	Open agricultural areas
Sparrow hawk*	Common	Agricultural areas with small woodlots
Sharp-shinned Hawk*	Uncommon	Forest land and forest open land edges
Black-crowned night heron*	Rare - inland, common - coastal	Ponds, lakes, rivers, bays and fresh or salt water marshes
Great blue heron* 2/	Uncommon	Ponds, lakes, rivers, bays and fresh or brackish marshes
Green heron*	Common to uncommon	Swamps, marshes, and slow rivers, especially with woody borders
Little blue heron* 3/	Rare	Fresh or salt water marshes
Yellow-crowned night heron*	Uncommon	Swamps and fresh or salt water marshes
Ruby-throated hummingbird*	Uncommon	Woodland openings, suburban gardens, areas with flowers
Eastern glossy ibis*	Rare	Wet meadows, ponds, mud flats, fresh or salt water marshes

Bird	Relative Abundance	Typical Habitat
Parasitic jaegar	Common to uncommon	Ocean
Pomarine jaegar	Uncommon	Ocean
Blue jay*	Abundant	Woodland edges, suburban areas
Dark-eyed junco*	Common	Shrub thicket, woodland edges, fields, suburbs
Killdeer*	Common	Bare ground, especially near water, pastures, mud flats
Eastern kingbird*	Common	Hedgerows, fence lines, shrubby streamsides, pond shoresides
Western kingbird	Rare - coastal	Agricultural land, suburbs
Belted kingfisher*	Uncommon	Ponds, lakes, streams
Golden-crowned kinglet*	Uncommon	Coniferous woodland, suburban areas
Ruby-crowned kinglet* 4/	Uncommon	Orchards, moist woodland, suburban areas
Black-legged kittiwake	Abundant - offshore	Sea cliffs, ocean
Knot	Common - coastal	Salt marshes, ocean shore, tidal flats
Horned lark*	Common - coastal	Hay fields, pastures, shore dunes, beaches
Lapland longspur	Uncommon - coastal	Fields, beaches
Common loon 2/	Uncommon	Large lakes, estuaries
Red-throated loon	Common - coastal	Ponds, lakes, estuaries and bays
Mallard*	Common	Ponds, lakes, large rivers, fresh or salt marshes, grain fields
Purple martin* 3/	Rare	Ocean shore, over fields
Eastern meadowlark*	Uncommon	Idle agricultural land, hay fields, wet meadows and marshes
Common merganser	Common	Undeveloped lakes, ponds, reservoirs, large rivers
Hooded merganser*	Uncommon	Undeveloped ponds, lakes, reservoirs, large rivers

Table I-12

BIRDS FOUND IN THE NORTH-SOUTH RIVERS BASIN AREA

Bird	Relative Abundance	Typical Habitat
Red-breasted merganser	Common - coastal	Undeveloped ponds, lakes, reservoirs, large rivers, ocean bays
Mockingbird*	Common	Farm land, suburban areas
Thick-billed murre	Uncommon - offshore	Ocean, bays, coast
Common nighthawk*	Common	Flat topped city buildings, open country
Red-breasted nuthatch*	Rare	Woodland, especially coniferous
White-breasted nuthatch*	Common	Deciduous woodland
Oldsquaw	Common	Deciduous woodland
Northern oriole*	Common	Suburban areas and farmland with elm trees
Orchard oriole*	Rare	Orchards, farmland with scattered woodlots
Osprey* 3/	Uncommon	Undeveloped river front lakes and large ponds
Ovenbird*	Common	Deciduous woodland
Barn owl*	Uncommon to rare	Woodland dges, agricultural land, abandoned barns
Barred owl*	Rare	Woodland swamps, wooded stream bottoms
Great-horned owl*	Common to uncommon	Remote woodland
Long-eared owl*	Rare	Coniferous or mixed woodland
Saw-whet owl*	Uncommon	Coniferous woodland, wooded swamps
Screech owl*	Uncommon	Agricultural land, open woods, suburban areas
Short-eared owl* 3/	Rare	Marshes, wet meadows, agricultural areas
Snowy owl	Uncommon	Coastal marshes, agricultural areas
American oystercatcher* 3/	Rare - coastal	
Northern parula 2/	Uncommon	Wooded swamps, woodland edges, orchards

Bird	Relative Abundance	Typical Habitat
Eastern wood pewee*	Common	Pine woodland, orchards, open woods
Northern phalarope	Uncommon - coastal	Ocean, coastal ponds and lakes, mud flats
Red phalarope	Rare - coastal	Ocean
Wilson's phalrope	Rare - coastal	Coastal ponds and lakes, mud flats
Ring-necked pheasant*	Uncommon	Abandoned fields, agricultural land, hedgerows
Eastern phoebe*	Common	Farms, suburban areas, orchards
Pintail	Uncommon	Marshes, ponds, undeveloped lakes, bays
Water pipit	Uncommon	Plowed fields, coastal dunes, mud flats
Black-bellied plover	Abundant to common	Ocean shoreline, salt mud flats
Piping plover*	Common - coastal	Ocean shoreline, sand dunes, mud flats
Semi palmated plover	Common	Ocean shoreline, wet meadow, mud flats
Clapper rail	Uncommon	Salt marshes
King rail*	Uncommon to rare	Fresh and salt water marshes
Virginia rail*	Common to uncommon	Fresh water marshes, wet meadows
Razorbill	Uncommon - offshore	Rocky offshore islands, ocean
Redhead	Uncommon	Ponds, lakes, large rivers, bays, especially coastal areas
Common redpoll	Uncommon	Fields, wooded swamps, shrub swamps
American redstart*	Common	Deciduous woodland, wooded swamps, suburbs
American robin*	Abundant	Suburbs, fields, woodland edges, hedgerows
Ruff	Rare - coastal	Salt marsh, ocean beach

Table I-12

BIRDS FOUND IN THE NORTH-SOUTH RIVERS BASIN AREA

Bird	Relative Abundance	Typical Habitat	Bird	Relative Abundance	Typical Habitat
Sanderling	Abundant - coastal	Ocean beach, tidal flats	Loggerhead shrike	Rare	Agricultural land and hedgerows
Baird's sandpiper	Uncommon to rare	Tidal flats, wet meadows, pond shore	Northern shrike	Rare	Orchards, wooded and shrub swamps, agricultural land
Buff-breasted sandpiper	Rare - coastal	Hay fields, pastures, wet meadows	Pine siskin*	Uncommon	Coniferous woodland
Least sandpiper	Abundant to common	Shorelines, mud flats, wet meadows	Black skimmer* 4/	Rare - coastal	Ocean bays
Pectoral sandpiper	Uncommon	Fresh and salt marshes	Common snipe	Common	Wet meadows, fresh or salt marshes
Purple sandpiper	Common - coastal	Ocean shore rocks and jetties	Sora	Common to uncommon	Fresh and salt water marshes
Semi palmated sandpiper	Abundant	Beaches, shore, tidal flats	Chipping sparrow*	Common	Conifer woodland, woodland edges, suburban areas
Solitary sandpiper	Rare	River and stream shores, ditches, marsh edge	Field sparrow*	Common	Field edges, idle agricultural land, shrub thickets
Spotted sandpiper*	Common	River, pond and stream shorelines	Fox sparrow	Uncommon	Shrub thickets, woodland edges
Stilt sandpiper	Uncommon	Shallow pools in fresh or salt marsh	Grasshopper sparrow* 3/	Uncommon	Hay fields, idle agricultural land
Upland sandpiper* 3/	Rare	Hay fields and pastures, wet meadows	House sparrow*	Abundant	Cities, suburban areas, farms
White-rumped sandpiper	Common to uncommon	Shorelines, fresh and salt marshes, mud flats	Ipswich sparrow	Rare - coastal	Beaches, sand dunes, especially those with beach grass
Western sandpiper	Uncommon to rare	Beaches, tidal flats	Lark sparrow	Rare - coastal	Pasture land, hay fields, idle agricultural land
Yellow-bellied sapsucker*	Uncommon	Orchards, woodland edges	Lincoln's sparrow	Uncommon	Hedgerows, shrub swamps, bogs
Greater scaup	Common	Ocean coast, lakes, large rivers, bays	Savannah sparrow*	Common	Pasture, hay fields, fresh or salt marshes, dunes
Lesser scaup	Common	Lakes, large rivers	Seaside sparrow*	Uncommon - coastal	Salt marsh
Black scoter	Common	Ocean coast	Sharp-tailed sparrow*	Common - coastal	Wet meadows, fresh and salt marshes
Surf scoter	Abundant - coastal	Ocean coast, bays	Shoveler	Uncommon	Brackish or fresh marshes, ponds
White-winged scoter	Abundant - coastal	Ocean coast, offshore islands, bays	Song sparrow*	Abundant	Shrub thickets, hedgerows, suburban areas
Cory's shearwater	Uncommon - coastal	Rocky ocean islands, offshore	Swamp sparrow*	Common to uncommon	Marshes, shrub swamps, idle agricultural land
Greater shearwater	Uncommon - coastal	Rocky ocean islands, offshore	Tree sparrow	Common	Shrub swamps, idle agricultural land, shrub thickets
Manx shearwater* 4/	Rare - coastal	Open ocean, rocky islands			
Sooty shearwater	Uncommon - coastal	Open ocean, rocky islands			

Table I-12

BIRDS FOUND IN THE NORTH-SOUTH RIVERS BASIN AREA

Bird	Relative Abundance	Typical Habitat
Vesper sparrow*	Uncommon	Pasture land, hay fields, idle agricultural land
White-crowned sparrow	Rare	Shrub thickets, woodland edges
White-throated sparrow*	Common	Shrub thickets, woodland edges, suburban areas
Starling*	Abundant	Suburbs, cities, agricultural land, woodland edges
Leach's storm-petrel* 3/	Rare - coastal	Open ocean, large bays, offshore islands
Wilson's storm petrel*	Uncommon - coastal	Open ocean
Bank swallow*	Uncommon	Wet meadows, steep banks, marshes, ponds
Barn swallow*	Common	Barns, farms, ponds, marshes, wet meadows
Cliff swallow*	Rare	Wet meadows, marshes, agricultural land
Rough-winged swallow*	Uncommon to rare	Over rivers, ponds, fields, steep river banks
Tree swallow*	Abundant	Open areas near water, marshes, shrub swamps
Chimney swift	Abundant	
Scarlet tanager*	Uncommon	Mature hardwood woodland, especially oak woodland
Blue-winged teal*	Uncommon	Fresh water ponds and marshes
Green-winged teal*	Uncommon	Marshes, ponds, undeveloped lakes
Arctic tern* 2/	Uncommon - coastal	Coast, ocean, lakes
Black tern	Uncommon - coastal	Coast, salt marsh
Caspian tern	Rare - coastal	Ocean coast, large lakes, bays, estuaries
Common tern*	Abundant - coastal	Coast, ocean shoreline, lakes
Forster's tern	Uncommon - coastal	Coast, fresh and salt marshes, lakes
Least tern*	Common - coastal	Ocean coast
Roseate tern* 3/	Common - coastal	Ocean coast
Royal tern	Rare - coastal	Ocean coast
Brown thrasher*	Common	Dry shrub
Common yellow throat	Common	Wooded swamps, shrub thickets
Gray-cheeked thrush*	Uncommon	Woodland, thickets
Hermit thrush*	Common	Shrub thickets, stream bottomland, moist woodland
Swainson's thrush* 3/	Common to uncommon	Woodland thickets
Wood thrush*	Common	Stream bottomland, moist woodland, suburban areas
Tufted titmouse*	Common	Deciduous woodland, wooded swamps, suburban areas
Rufous-sided towhee*	Common	Shrub thickets, woodland edges, dry woodland
Ruddy turnstone	Common - coastal	Ocean beach, mud flats, jetties
Veery*	Common	Wooded swamps, woodland stream bottoms
Philadelphia vireo	Uncommon	Hardwood woodland, especially near water, woodland edges
Red-eyed vireo*	Common	Hardwood woodland, suburban areas
Solitary vireo*	Uncommon	Coniferous woodland and mixed coniferous-hardwood woodland
White-eyed vireo*	Uncommon to rare	Shrub thickets and young woodland, particularly near water
Yellow-throated vireo*	Rare	Hardwood woodland, suburban areas, orchards
Bay-breasted warbler	Uncommon	Bogs, openings in softwood woodland
Black-and-white warbler	Common	Hardwood woodland

Table I-12

BIRDS FOUND IN THE NORTH-SOUTH RIVERS BASIN AREA

Bird	Relative Abundance	Typical Habitat
Black-throated green warbler*	Common to uncommon	Coniferous woodland
Blackburnian warbler*	Uncommon	Coniferous woodland
Black poll warbler*	Common to uncommon	Near bogs, coniferous woodland
Brewster's warbler 3/	Uncommon to rare	Shrub thickets, woodland edges
Canada warbler*	Common to uncommon	Shrub thickets, especially near water
Cape May warbler	Uncommon	Coniferous woodland, woodland edges
Connecticut warbler	Uncommon to rare	Wooded swamps
Hooded warbler* 4/	Uncommon	Shrub thickets, especially near water
Magnolia warbler*	Common to uncommon	Young coniferous woodland, woodland edges
Mourning warbler* 3/	Rare	Wooded swamps
Myrtle warbler*	Common	Coniferous woodland, coastal shrub thicket areas
Nashville warbler*	Uncommon to rare	Woodland edges, orchards, shrub thickets, pond edges
Orange-crowned warbler	Uncommon	Wooded stream bottom land, open woods, pond edges
Palm warbler	Common	Bogs, open woods, suburban areas
Pine warbler	Common	Coniferous woodland, shrub thicket, mixed woodland
Prothonotary warbler*	Rare	Wooded stream bottom land, wooded swamps
Tennessee warbler	Uncommon	Coniferous woodland, shrub thickets, suburban areas
Wilson's warbler	Uncommon to rare	Marshes, shrub swamps
Yellow warbler	Common	Wooded swamps, wooded stream or pond edges

Bird	Relative Abundance	Typical Habitat
Louisiana waterthrush*	Common to uncommon	Wooded stream bottom land
Northern watershrush*	Common	Wooded stream bottom land, woodland bordering ponds, wooded swamp
Cedar waxwing*	Uncommon	Woodland edges, open woodland, orchards, suburban areas
Whimbrel	Common to uncommon	Salt marshes, tidal flats, ocean shore
Whip-poor-will*	Uncommon	Woodland edges
American wigeon	Uncommon to common	Large rivers, marshes, lakes, bays
European wigeon	Rare - coastal	Large rivers, marshes, lakes, bays
Willet 4/	Uncommon - coastal	Fresh and salt marshes, ocean beach, tidal flats
American woodcock	Common	Shrubby wet meadows, shrub thickets or young woodland along streams
Downy woodpecker*	Common	Open woodland, woodland edges
Hairy woodpecker	Uncommon	Woodland
Red-headed woodpecker* 4/	Rare	Orchards, hedgerows, open woods
Carolina wren*	Uncommon to rare	Shrub thickets, wooded swamps, woodland
House wren*	Uncommon	Woodland edges, shrub thickets, hedgerows
Long-billed marsh wren*	Common	Fresh and salt marshes
Short-billed marsh wren* 4/	Rare	Fresh and salt marshes
Winter wren*	Uncommon to rare	Shrub thickets,, streamside woodland
Greater yellowlegs	Common	Marshes, mud flats, slow moving streams, wet meadows
Lesser yellowlegs	Uncommon	Marshes, wet meadows, shallow ponds, mud flats

* Massachusetts breeding bird.

1/ This species is listed under the provisions of the Federal Endangered Species Act of 1973 (Federal Register 41(208):47180-47198. This species is classified by the Act as endangered.

2/ Listed in 1979 Massachusetts Species for Special Consideration. Fauna of Massachusetts, Series No. 5. Classified as State Rare.

Table I-13

Amphibians Found in the North-South Rivers Basin Area

Amphibian	Relative Abundance	Typical Habitat
Bull frog	Abundant to common	Lakes, ponds, bogs, large slow streams.
Green frog	Abundant	Lakes, ponds, marshes, streams.
Northern leopard frog	Common	Fresh meadow wetland and wooded swamps.
Pickerel frog	Common	Near ponds, bogs, and streams. Often in fresh meadow wetland.
Wood frog	Common	In or near moist woodland.
Red spotted newt	Abundant	Adult - ponds, small lakes, marshes, slow moving streams. Immature - moist woodland.
Spring peeper	Abundant	Brushy or wooded areas near ponds, marshes, or swamps.
Marbled Salamander 1/	Uncommon	Upland woodland except during breeding season.
Northern dusky salamander	Common	In or near springs, seeps and small brooks in wooded areas.
Northern two-lined salamander	Common	Wet areas along springs and stream edge.
Red-backed salamander	Abundant	Under forest litter (bark, logs) and stones in woodland.
Spotted Salamander 1/	Uncommon	Woodland near ponds and slow streams.
American toad	Common	Backyards to remote areas. Prefers dark, moist hiding place during day.
Fowler's toad	Uncommon	Sandy areas around lake shores and in river valleys.
Gray treefrog	Common	Shrub swamps. Forages in shrubs and small trees.

1/ Listed in 1979 Massachusetts Species for Special Consideration, Fauna Series No. 5, and classified as "State Local" defined as: long-established species in the Commonwealth that are restricted to very limited areas. May be widespread but is nowhere frequent.

Table I-14

Reptiles Found in the North-South Rivers Basin Area

Reptile	Relative Abundance	Typical Habitat
Northern black racer	Common to Uncommon	Variable, brushy fields, stone walls, rocky hillsides, wooded swamps, fields.
Eastern garter snake	Abundant	Variable, fields, woods, hills, suburban areas, wet meadows, near springs, streams, wetlands.
Eastern hognose snake	Common to uncommon	Fields, and open woods particularly in dry sandy areas.
Eastern milksnake	Common	Fields, open woods, particularly in areas of sandy soils.
Eastern ribbon snake	Common	Near ponds, streams, wet meadows, swamps and other low, moist places.
Northern brown snake	Common	Under stones, boards or other debris in any habitat vacant city lot to rural area.
Northern ringneck snake	Common	Under rocks, logs, or other debris in moist woodland and moist field edges.
Northern water snake	Common	Near water such as streams, ponds, marshes, and lakes.
Red-bellied snake	Common	Under logs, stones, bark and other forest debris especially in rocky woodland.
Smooth green snake	Uncommon	Open areas such as fields, orchards, wet meadows and gardens.
Atlantic leatherback	Endangered 1/	Open ocean.
Stinkpot	Uncommon	Ponds, lakes, reservoirs, and slow streams.
Eastern box turtle	Uncommon	Moist woodland, pasture, hay fields, primarily lives on land.
Eastern painted turtle	Abundant	Shore of ponds, lakes, reservoirs, marshes, and slow streams.
Snapping turtle	Common	Any permanent fresh water except high velocity streams.
Spotted turtle	Common	Ponds, marshes, bogs, swamps, and very slow streams.
Wood turtle	Uncommon	Ponds, marshes, slow streams, wet fields, swamps, and moist woodland.

1/ The Atlantic leatherback is listed under provisions of the federal Endangered Species Act of 1973 (Federal Register 41(208):47180-47198). This species is classified under the act as endangered.

Table I-15

Mammals Found in the North-South Rivers Basin Area

Mammal Species	Relative Abundance	Typical Habitat
Big brown bat	Common	Caves, hollow trees in woodland, abandoned buildings. Cities to wilderness.
Hoary bat 1/	Uncommon	Woodland.
Red bat	Common	Woodland, usually roosts in trees.
Silver-haired bat	Common	Woodland, especially near water.
Little brown myotis	Common	Roosts in caves, hollow trees, buildings.
Eastern pipistrel	Common	Caves, abandoned buildings, wooded areas, especially near water.
Beaver	Uncommon	In and along streams, ponds, and undeveloped lakes.
Eastern chipmunk	Abundant to common	Woodland, particularly rocky woodland, stone walls, woodland edges, suburbs.
Whitetail deer	Uncommon	Rural woodland and open fields.
Gray fox	Uncommon	Rural woodland.
Red fox	Uncommon	Mixture of woodland and open agricultural land.
Mink	Uncommon	Along streams, ponds, marshes and undeveloped lakes.
Eastern mole	Common	Well drained soil of open agricultural lands.
Starnose mole	Common to uncommon	Moist areas near streams.
House mouse	Abundant	Usually in buildings, rarely in fields.
Meadow jumping mouse	Common	Fresh meadow wetland, moist areas near streams.
White-footed mouse	Common	Hardwood woodland or mixed lardwood-softwood woodland. Often near streams.
Woodland jumping mouse	Common	Moist wooded areas, often along streams.
Muskrat	Abundant to common	Marshes, ponds, shallow lakes, slow moving streams.
Virginia Oppossum	Common to uncommon	Agricultural areas and mixed farming and woodland areas especially near streams.
River Otter	Uncommon	Along streams, ponds, marshes and undeveloped lakes.
Eastern cottontail rabbit	Abundant	In or near agricultural land, idle agricultural land, brush lots, suburbs.
New England cottontail rabbit	Uncommon	Brushy areas and woodland.
Raccoon	Abundant	Woodland, swamps, often in or near agricultural land.
Norway rat	Common	Houses, abandoned buildings, farms, fields especially near streams.
Harbor seal	Common	Harbors and near shore.
Masked shrew	Common	Moist areas varying from salt marsh to upland sites.
Short-tailed shrew	Abundant to common	Anywhere with vegetative litter.
Striped skunk	Abundant	Woodland and open land. Suburban to rural lands.
Eastern gray squirrel	Abundant	Hardwood woodland, city parks, suburbs.
Red squirrel	Common to uncommon	Softwood woodland or mixed woodland.
Southern flying squirrel	Uncommon	Mature woodland.
Meadow vole	Abundant	Idle agricultural land, hayfields.
Pine vole	Uncommon	Hardwood woodland, hayfields, orchards.
Longtail weasel	Uncommon	Woodland, wooded swamps, and open land.
Shorttail weasel	Common	Woodland, usually close to water.
Woodchuck	Abundant to common	Woodland edges, hayfields, hedgerows, and pasture-land.

1/ Listed in 1979 Massachusetts Species for Special Consideration, Fauna Series No. 5, and classified as a "Peripheral Breeding Species" defined as species which "reach the limits of their normal breeding distribution in Massachusetts."

Table I-16

Fish Found in the North South
Rivers Basin Area (Fresh or Brackish Areas)

Fish Species	Relative Abundance	Typical Habitat
Alewife	Abundant	Ocean, ascend fresh water streams in spring to spawn.
Largemouth bass	Abundant	Ponds, lakes and slow rivers.
Smallmouth bass	Common	Ponds, lakes and large rivers, especially with rocky bottoms.
Striped bass	Uncommon	Lower portions of large coastal rivers.
Bluegill	Abundant	Ponds, lakes, slow rivers.
Brown bullhead	Abundant	Mud-bottomed ponds, lakes and large, slow rivers.
Yellow bullhead	Uncommon	Shallow water of large ponds, lakes and slow rivers.
Carp	Common	Shallow ponds and lakes, slow rivers.
Black crappie	Abundant	Ponds and lakes.
Swamp darter	Uncommon	Coastal streams and ponds.
Tesselated darter	Abundant to common	Streams and rivers.
American eel	Abundant	Ocean. Female immature ascend rivers to mature. Estuaries.
Fallfish	Abundant	Streams and rivers. Occasionally in ponds and lakes.
Goldfish	Common	Shallow ponds and lakes.
Grubby	Common	Brackish water of coastal streams.
Blueback herring	Abundant to common	Ocean, ascend fresh water streams in spring to spawn.
Hogchoker	Common	Brackish bays and estuaries.
Banded killifish	Abundant	Weedy portions of lakes, rivers and estuaries.
Striped kililfish	Common to uncommon	Brackish water of coastal streams and salt water bays.
American brook lamprey	Rare	Coastal river drainage.
Sea lamprey	Common	Adults-ocean; larvae-large rivers. Adults ascend fresh water streams to spawn.
Mummichog	Abundant	Fresh, brackish and saline waters. In salt marshes, bays and other estuarine waters.
White perch	Abundant	Ocean-near shore. Estuarine waters. Fresh water ponds and lakes.
Yellow perch	Abundant	Fresh water ponds and lakes.
Chain pickerel	Abundant	Large slow rivers, ponds, shallow lakes.
Redfin pickerel	Common	Slow streams and rivers, marshes, ponds.
Northern pipefish	Common	Ocean. Among seaweed in shallow water. Estuaries.
Pumpkinseed	Abundant	Ponds, lakes, and slow streams.
Coho salmon	Uncommon	Ocean. Ascends North River to spawn. Dependent on stocking by state.
American shad	Common	Ocean. Ascends fresh water rivers in spring to spawn.
Bridle shiner	Common	Streams and rivers.
Common shiner	Common	Streams and rivers.
Golden shiner	Abundant	Ponds, lakes and slow streams.
Spottail shiner	Common	Streams and rivers.
Atlantic silverside	Abundant	Abundant in brackish coastal streams. Ascends coastal streams to fresh water.
Rainbow smelt	Abundant	Ocean, ascend fresh water streams in spring to spawn.
Fourspine stickleback	Common	Common in brackish coastal streams. Ascends coastal streams to fresh water.
Ninespine stickleback	Common	Common in brackish coastal streams. Ascends coastal streams to fresn water.
Threespine stickleback	Common	Common in brackish coastal streams. Ascends coastal streams to fresh water.
White sucker	Abundant	Streams, rivers, ponds, lakes.
Banded sunfish	Uncommon	Ponds, lakes, slow streams.
Redbreast sunfish	Uncommon	Ponds, lakes, slow streams.
Atlantic tomcod	Uncommon	Coastal and estuarine waters. Ascends coastal streams to fresh water.
Brook trout	Common	Cool water streams. Stocked annually by state.
Brown trout	Common	Cool water streams, deep ponds and lakes. Stocked annually by state.
Rainbow trout	Uncommon	Cool water streams. Stocked annually by state.

C. Other Unique Areas

Within a community, there are many items or areas which are generally considered by local residents to be unique or unusual. Although an item may be commonplace in other regions, it may be unusual in the local area. Unique areas are simply those areas considered to be unique by local residents. These include natural areas, beaches and dunes, views or significant visual resources, interesting landforms, buildings, unusual or old trees, etc. Lists of such unique areas were provided by town boards, commisions, town advisory groups, and various interest groups and are presented in Table I-17.

Table I-17

Duxbury

- Duxbury Beach including Powder Point Bridge
- Duxbury Bay
- Great Salt Marsh
- Standish Monument (Miles Standish State Park)
- Duck Hill Road
- Blue Fish River from St. George Street
- Kingston Bay from Chestnut Street
- West Brook
- Mill Pond
- Island Creek Pond
- Pine Lake
- South River and adjacent lands
- Keene's Mill Pond
- Phillips Brook
- South River Reservoir
- Upper and Lower Chandler Ponds
- Historic Main Street

Hanson

- Rocky Run (Hanson/Hanover line)
- Poor Meadow Brook (Main Street, easterly)
- Town Hall building (Liberty Street)
- Camp Kiwanee (along Maquan Pond)
- Cranberry Cove (beach on Maquan Pond)
- State Street bridge (over North River)
- Fern Hill Cemetary (High Street)
- Church of the First Born (Route 58)
- Congregational Church (Main Street)

Hanover

- Shinglemill Brook
- Longwater Brook
- Pine Island Swamp
- Drinkwater River
- Forge Pond
- Fireworks
- Factory Pond
- Peg Swamp
- Well Swamp
- Curtis Crossing
- Hanover Center
- Silver Brook
- Third Herring Brook
- Peterson Pond
- Thimbledam Hill

Marshfield

- Rexhame Dunes (Standish Street)
- Old Rexhame (Winslow Street)
- South River marshes
- North River marshes and head lands
- Carolina Hill
- Green Harbor River basin
- Winslow Cemetary
- Memorial Park (intersection of Routes 139 & 34)
- Church and cemetaries (intersection of Routes 139 & 34)
- Hatch Mill (Union Street)
- Winslow House and vicinity (Rt. 139 and Webster Street)
- Ponds along roadways throughout town
- Nelson Hill (Highland Street)
- Adelaide Phillips House (Webster Street)
- Duxbury marshes (Careswell Street)
- Holly Hill

Norwell

North River and adjacent marshes

Accord Pond

Jacobs Pond

Burnt Plain Swamp

Black Pond and adjacent swamp

First Herring Brook

Buttonwood Hill

Town Hall building

Kings Landing

Old First Parish Church and cemetery

Simon Hill

Turner Pond

Torrey Pond

Stoney Brook

Second Herring Brook

Hop Pole Swamp

Hatch Pond

Mount Blue

Otis Hill

Wildcat Brook

Pembroke

Herring River

Brick Kiln (old shipyard)

Briggs and Mercy's (old shipyard)

Shepherd Memorial Forest off Mattakesett Street)

Veterans Forest along School Street

Brick Street Forest

Abandoned cranberry bog on Elm Street

Old pound in center of town

Cedar Swamp (from Herry Run to North River)

Misty Meadow area (off Route 53)

Stump Pond (cranberry reservoir)

Peter's Well

Rockland

Hartsuff Park (off Hingham Street)

Water Department and reservoir (off Hingham Street

Memorial Stadium

1745 House

Pine Grove area (North Avenue)

Studley Pond (Centre Street)

Scituate

Old railroad station on First Parish Road

Greenbush Pond (intersection of Routes 123 and 34)

4 cliffs on ocean

Lawson Tower on First Parish Road

Harbor basins along coast

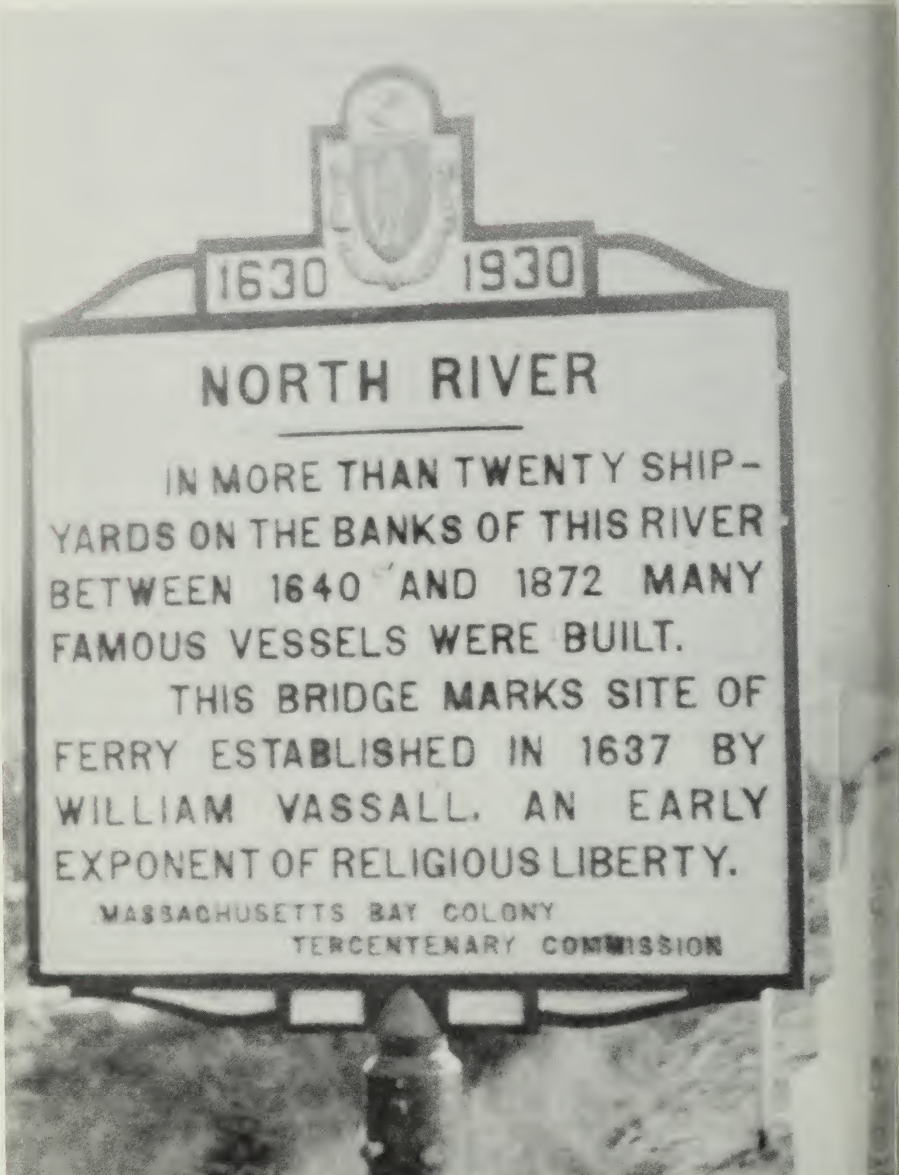
North River marshes on south end of town

Lawson Park in center of town

First Herring River and adjacent lands

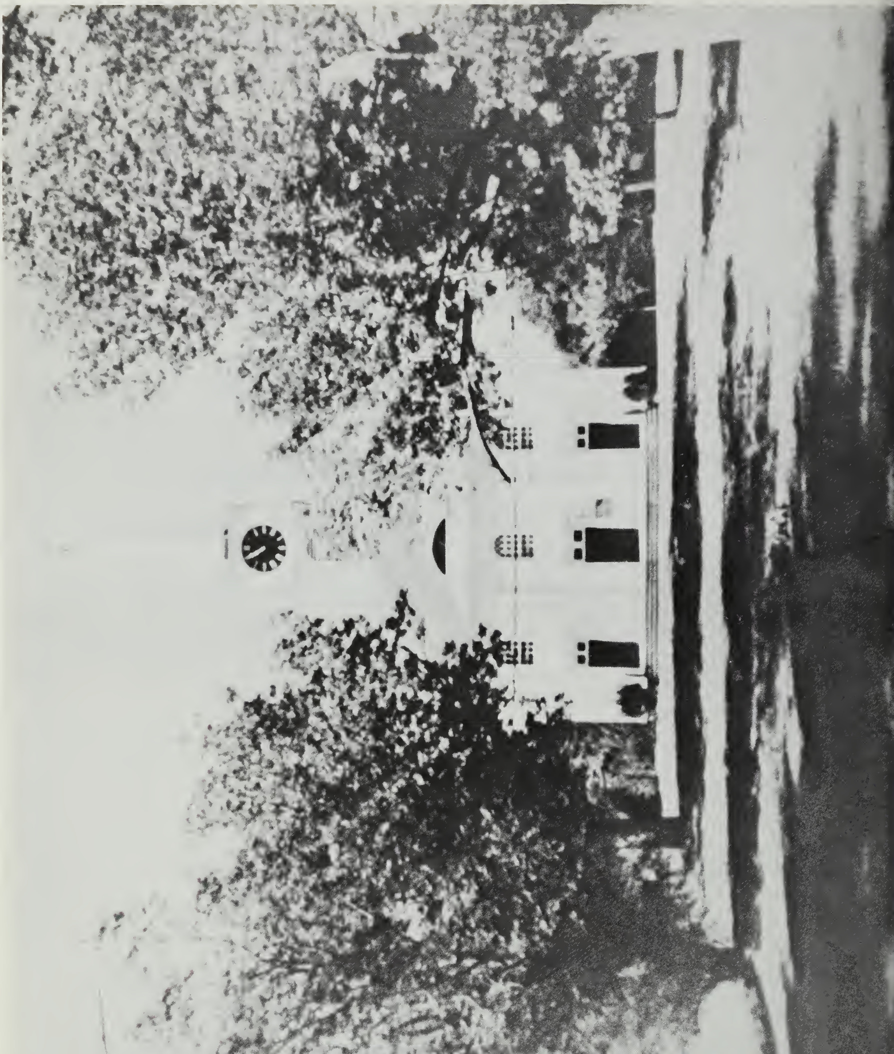
Pincin Hill area

Gulph River and adjacent marshes


1630 1930
NORTH RIVER
IN MORE THAN TWENTY SHIP-
YARDS ON THE BANKS OF THIS RIVER
BETWEEN 1640 AND 1872 MANY
FAMOUS VESSELS WERE BUILT.
THIS BRIDGE MARKS SITE OF
FERRY ESTABLISHED IN 1637 BY
WILLIAM VASSALL, AN EARLY
EXPONENT OF RELIGIOUS LIBERTY.
MASSACHUSETTS BAY COLONY
TERCENTENARY COMMISSION

Appendix II

PUBLIC PARTICIPATION



APPENDIX II

NORTH AND SOUTH RIVERS BASIN

Public Participation

The public participation process in the Massachusetts River Basin Planning Program is intended to provide assistance by supplying the guidelines and technical expertise that help local officials and citizens understand and interpret the inter-relationships among natural resources and land uses. This understanding helps local people formulate and implement a community-based basin land and water use plan.

The Massachusetts River Basin Planning Program is designed to build on community initiative. The Program uses the information and public participation framework developed at the community level to address planning issues that concern several communities and/or entire river basins. In other words, the MRBPP public participation process is designed to help communities work together to solve intercommunity and basin-wide water and related resources roblems.

Public participation has been an integral part of each phase of the North and South Rivers Basin Planning Program, from initial data collection to resource decision-making. Public participation has led to increasing the public awareness of existing and potential land and water and resource problems and alternative solutions.

The public participation program's overall goals are to:

1. encourage citizen participation in the planning process by supplying the procedures and techniques which enable local citizens to inventory and evaluate the natural resources in their area;

2. inform local citizens and decision-makers about natural resources and thereby encourage individual communities and basin groups to take actions for sound natural resource management, protection, and use;

3. help citizens and decision-makers to utilize the technical assistance which is available from state and federal agencies.

The Massachusetts River Basin Planning Program in the North and South Rivers Basin has worked to attain these goals by a variety of mechanisms.

Initial Review and Comment

Early in the basin program development stage, comments were solicited from the participating towns. Copies of the draft Plan of Work for the North and South Rivers Basin Planning Program were distributed to all Conservation Commissions, Planning Boards, and Boards of Selectmen in the eight towns. Many sent written comments and/or letters of endorsement. In addition, several intertown review meetings were held to give interested townspeople an opportunity to discuss the Plan of Work proposals. Two meetings were held: November 14, 1978, in Marshfield, and November 20, 1978, in Hanover. Individual town boards and commissions were also solicited for verbal comments via open space planning or other meetings. These comments were used to structure the final basin program.

Town Advisory Groups

A continuous source of public involvement in the MRBPP at the community level has been the Town Advisory Group or "TAG." The TAG is comprised of a volunteer Steering Committee and Coordinator. The TAG is the group responsible for the overall process of the town's resource planning activities, especially coordinating with town boards, commissions, and interest groups.

In the basin towns, the Conservation Commission served as the Town Advisory Group, with the exception of the town of Hanson, where the Recreation Commission served as the spearhead.

Specifically, the TAG's in each town:

1. determined initial resource goals and objectives;

2. recruited and organized volunteers to prepare inventories and collect resource data;

3. coordinated public information activities including public meetings;

4. coordinated with local town boards, interest groups, and resource agencies;

5. synthesized resource evaluations and findings;

6. prepared plans and recommendations.

Volunteer sub-committees assisted the TAG's in specialized areas primarily for surveying, gathering, and preparing resource and land use base information.

Town Open Space Plans

Several towns in the North and South Rivers Basin organized special committees to prepare open space and recreation plans. Much of the town volunteer work entailed conducting detailed inventories of recreation facilities, significant cultural and historical areas, and other associated data. These data were analyzed to determine community and regional demands for additional recreation and to flag important resource areas. These plans resulted in formulating a five-year course of action for resource protection and recreational development. Citizens at large have supported these plans by voting to appropriate funds for the acquisition of priority conservation and recreation lands.

a. Open Space Plan Sub-Committees

Approximately 70 citizens were organized within six of the eight basin towns to prepare inventories and written sections for open space type plans. Participation as well as the end result varied with each town. Generally, citizens associated with the individual town Conservation Commissions comprised the bulk of the volunteers. Volunteers in each town included:

Duxbury

Dr. Lansing Bennett, Conservation Commission
John Borgeson, Parks Department
Kay Foster, Conservation Commission
James Kelso, Board of Selectmen
Frank LeSeur, Recreation Department
Roberta Nickerson, Conservation Commission
James Spirale, Conservation Commission

Hanover

Marjorie Abbot, Conservation Commission
Philip Beal, Department of Public Works
Donald Deluse, Conservation Commission
James Harney, Conservation Commission
Lois Heim, Conservation Commission
John Libertine, Planning Board
Leslie Molyneaux, Conservation Commission
Diana Morris, Recreation Commission
Jean Nichols, Conservation Commission
Janet O'Brien, Board of Selectmen
Katherine Townsend, Conservation Commission
Frank Wallen, Department of Public Works
Ronald Whitt, Recreation Commission

Hanson

Wes Blauss, Recreation Commission
Paul Cameron, Planning Board
Wallace Darsch, Water Department
Kevin Franzosa, CETA
Donald Jepson, Conservation Commission
Russell LePorte, Conservation Commission
Philip Lindquist, Planning Board
Steve Morullo, Conservation Commission
Richard Moodie, Recreation Commission
Peter Nawazelski, Conservation Commissiom
Mary Puleio, Recreation Commission
Michael Sikova, Conservation Commission
Elton Smith, Conservation Commission
Kathleen Turner, Recreation Commission
Susan Webster, Planning Board

Norwell

Bill Bodio, Recreation Commission
Katherine Cranton, Conservation Commission (ret.)
Carol Cushing, Conservation Commission
William Frado, Jr., Planning Board
Judy Griffin, Planning Board
Wes Osborn, Conservation Commission
Judy Sheehan, Conservation Commission

Pembroke

Katherine Catoni, Conservation Commission
Robert Dow, Recreation Commission
Richard Fisher, Conservation Commission
Robert Gillette, State Representative
Gene McSherry, Recreation Commission
Ann Radwin, Conservation Commission
Bob Reardon, Jr., Conservation Commission
Les Smith, Conservation Commission
James Smithson, Conservation Commission
Frank Wallen, Department of Public Works
Arlene Walsh, Conservation Commission

Scituate

Robert Drew, Recreation Commission
Evelyn Ferreira, Board of Selectmen
Elinor Folley, Conservation Commission
Corinne Higgins, Conservation Commission
Faith King, Planning Board
Clare McDonough, Conservation Commission
Dr. Carl Pipes, Board of Selectmen
Alice Proctor, Board of Selectmen
Gene Pipes, Conservation Commission
William Richardson, Conservation Commission
Charles Sparrell, Jr., Conservation Commission

b. Land Use Data

Land use data were updated and mapped on 1 inch equals 1000 foot scale maps by these volunteer inventory groups. 1971 Land Use and Vegetative Cover Maps derived from the Massachusetts Map Down remote sensing project were used as preliminary land use maps. Based on field checking, these maps were revised to depict current land uses. Inventory committees were organized on a neighborhood basis or similar scale to inventory areas familiar to local volunteeers. These individual community land use maps were later assembled to produce a basin-wide land use map.

c. Other Resource Data

In addition to land use maps, information was gathered in a number of resource areas. These include: groundwater availability, wetlands, public and quasi-public lands, historical sites, unique areas, flood hazard areas, recreation facilities, and others. The towns of Hanover, Hanson, Pembroke, and Scituate prepared a thorough set of land use and resource maps while Duxbury and Norwell had similar sets previously prepared.

Public Involvement in Technical Aspects

Town Advisory Groups and sub-committees in each of the participating towns were directly involved in the gathering and evaluation of resource information for the Basin. Their contribution toward supplying data for many of the planned Items of Work proved to be invaluable to the study's efforts and resulted in greater community awareness of resource constraints and opportunities. Data for several significant Items of Work were obtained by these community volunteer groups.

a. Water Supply and Water Quality

Town Water Departments, Boards of Public Works, Health Departments, Conservation Commissions, and other departments were instrumental in supplying data on local water supplies, water quality, and use. Town Water Departments supplied much needed site-specific data, especially test boring logs, location maps of well fields, utility lines, plans for future water resource development, etc.

b. Water Quality/Hazard Areas

Town Water Departments, Health Departments, Conservation Commissions, and others supplied information on existing water quality in streams, well fields, and surface reservoirs. Underground gas storage facilities, existing and abandoned landfill sites, sewage treatment discharges, heavily salted roadways, etc., were also located and mapped.

Public Meetings/Information Program

To aid in coordinating individual town planning efforts, periodic meetings were held to discuss inter-town problems, review river basin progress, and to disseminate ideas on land and water resource management. In addition to numerous meetings held with individual town boards and commissions, several inter-town or basin-wide meetings were held to review and comment on the North and South Rivers Basin Plan of Study. Comments received verbally at these meetings and by mail were helpful in establishing priorities for those Items of Work the basin residents deemed important.

Coordination with state agencies, regional planning agencies, interest groups, and the watershed association provided opportunities to involve and inform these groups via their regular public meetings. Such groups included: the Massachusetts Division of Water Resources, the North and South Rivers Watershed Association, the Metropolitaan Area Planning Council, the Old Colony Planning Council, the Massachusetts Cooperative Extension Service, the Massachusetts Department of Fisheries, Wildlife and Recreational Vehicles, the Massachusetts Department of Environmental Management (Scenic Rivers), the Office of Coastal Zone Management, the Massachusetts Department of Environmental Quality Engineering, and the Divisions of Fisheries and Wildlife, and Forests and Parks, as well as numerous civic and special interest groups.

Future Public Participation in River Basin Planning

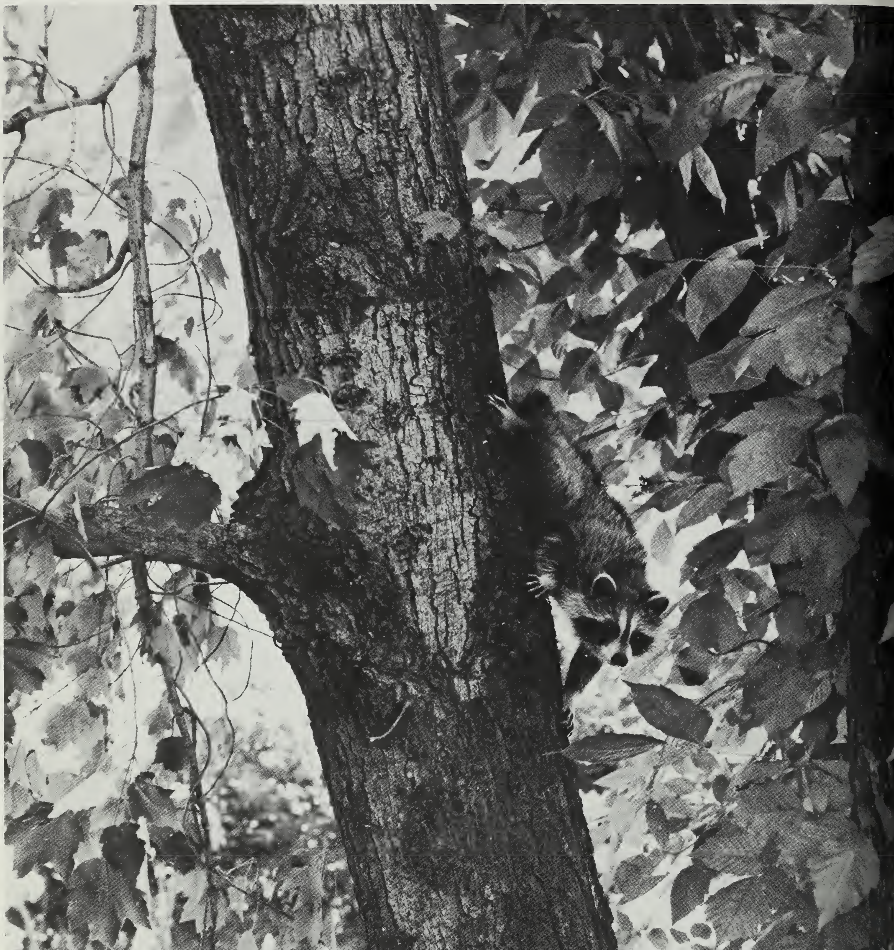
River basin planning is a continuing activity and, as such, must rely on continuing public involvement to insure success in following through with resource management activities. While there are a number of well established and active basin groups who act as resource advocates and who can be expected to maintain a continuous program, the importance of encouraging local action consistent with basin goals and priorities on the part of town and private citizens should be stressed.

Activities are carried out by diverse groups and at various levels, often independently and for different purposes. Town departments, state and federal agencies, as well as private developers and citizens, make decisions affecting land and water use on a daily basis. An understanding of the opportunities and constraints to a river basin's resources not only complements the social, economic, and political concerns, but also it can provide a broader dimension to the decision-making process.

Public sentiment is an important consideration. Those who are accustomed to preparing planning proposals are well aware of the need for a wide base of public support to assure success in implementing their projects. It is essential that basin residents be informed and involved so that good recommendations are not defeated by misunderstandings, a lack of interest, or a lack of communication. Hopefully, the interest generated so far in the North and South Rivers can be maintained, if not expanded, in the future.

Appendix III

FOREST RESOURCES



APPENDIX III

THE FOREST RESOURCES OF THE NORTH AND SOUTH RIVERS BASIN

INTRODUCTION

Forestland covers 46,000 acres (46 percent of the area) representing the major land use in the eight towns of the North and South Rivers Basin (Table III-1). However, 20,000 acres of forestland have disappeared since 1950 primarily because during the 1950's and 1960's, the opening of a major highway between Boston and Cape Cod led to the rapid development of the Basin. Population and average household income increased, and much of the land changed to suburban/urban uses. However, today the Basin still remains primarily wooded.

Table III-1. Forestland in 1951, 1971, and 1980 for Towns in the North and South Rivers Basin

Town	Total Land Area	Forestland 1951	Forestland 1971	Forestland 1980
Duxbury	15,454	9,824	8,095	6,525
Hanover	9,978	7,187	5,979	5,162
Hanson	9,971	6,441	5,556	5,218
Marshfield	18,678	11,064	9,498	6,760
Norwell	13,133	10,417	9,141	8,173
Pembroke	15,284	11,135	9,191	7,785
Rockland	6,421	4,083	3,534	2,508
Scituate	11,281	6,092	4,725	4,088
Total	100,200	66,243	55,719	46,219

Source: 1951 and 1971 figures are from William P. MacConnell, Remote Sensing 20 Years of Change, Plymouth County, Massachusetts, 1951-1971, Cooperative Extension Service, University of Massachusetts, Amherst, 1973. 1980 forestland acreage supplied by USDA's Soil Conservation Service.

FORESTLAND CHARACTERISTICS AND FOREST PRODUCTS SUPPLY

White pine and various oak species dominate the tree composition. Red maple is abundant, particularly in the lowland and swampy areas. In 1972, the year of the last statewide forest survey, the commercial forestland in Plymouth County was classed at 34 percent sawtimber-sized stands, 25 percent poletimber-sized stands, 36 percent sapling-seedling stands, and 5 percent nonstocked areas. The size of trees present on forestland is important from the viewpoint of sustained yields of wood fiber and for purposes such as wildlife habitat management. The average volume of growing stock is approximately 15 cords per acre. Fifty-three percent of that volume is estimated to be in sawtimber-sized trees and 47 percent in poletimber-sized trees. A resurvey scheduled to begin in Massachusetts in 1983, will provide updated information on the forest resources in Plymouth County.

The supply of timber in a physical sense is the volume of wood fiber volume that is on the 46,000 acres presently classed as forestland. The term "growing stock" is used to describe all trees of commercial species except rough and rotten trees. Growing stock volumes are estimated as the volume of wood between measured points on the tree summed for the area. The growing stock volume does not include the stump, top, and branches. Traditionally, foresters use growing stock as an indicator of volume. Another term which is gaining increasing recognition in describing the wood volume in a tree is biomass. This term usually includes the leaves and root system and may include all vegetation growing on a tract of land. In this appendix, biomass refers only to the woody material above ground level when referencing wood products. The difference in wood fiber volume between growing stock and biomass is substantial. Growing stock is the lesser of the two volumes and can be up to one-half the biomass volume. Put another way, adding in the topwood (top of stem, limbs and branches) and, to a small degree, the volume of wood left on the stump, the estimated volume of biomass may be up to two times greater than the growing stock volume estimate. In terms of forest product use, the distinction is quite important. In utilizing trees for fuelwood, essentially the entire tree can, and often is, cut up and burned. Pulp companies using whole tree chippers can also use the entire tree. A lumber mill cutting dimension boards cannot, understandably, use the entire tree.

The available supply of wood fiber is usually substantially less than the physical supply primarily because many owners have no intention of cutting trees for wood products, with the possible exception of firewood. Additional reasons may be that there are few markets available to those who wish to harvest their trees (size-classes of trees on particular parcels may not be marketable for wood products; or the location of mills may be too distant and thus high transportation costs result in forcing stumpage prices down to unacceptable levels; or the species represented may not presently be in demand by the users of wood products). Further, landowners will continue to weigh their perceived aesthetic recreational and/or wildlife values of their forestland versus the values of harvesting for wood product production.

The present condition of the forestland in the Basin has resulted from a myriad of factors, some man-made and others natural (abandonment of pastures and fields under pressures of development, and such natural things as the 1938 hurricane) have resulted in basically even-aged stands. The forests are largely unmanaged, and most stands are overstocked. The trees are crowded together since they have not been thinned in recent decades, resulting in an overall growth rate that is below potential. If the forestland were to be improved, substantial thinning and weeding of dead, crowded, and inferior trees would be required in order to promote improved growth and quality among the remaining trees. It is estimated that initial thinnings in such unmanaged stands would produce at least 5 cords per acre. In terms of annual growth, utilizing the growing stock method of estimating the volume of wood fiber (approx. 1/2 cord/acre/year), it is estimated that the Basin could provide a potential sustainable yield of 23,000 cords. Utilizing the biomass estimation technique, and assuming .9 cords/acre/year, a potential sustainable yield of nearly 42,000 cords could be provided each year. However, potential supply far exceeds actual supply since forestland owners have conflicting ownership goals, and varying productivity levels on their forestland. The institutional, social and economic constraints mentioned previously also limit actual supply. These factors result in a relatively small proportion of the potential supply being available for use in any given year.

DEMAND FOR FOREST PRODUCTS

The forest resources of the Basin are subjected to a number of demands: recreation, watershed protection, cordwood production, and sawlog production. During the 19th Century, demands on the forests were from cordwood and charcoal production and the clearing for pasture and cropland. Early in the 20th Century, the abandonment of farmland changed the landscape, with land reverting to woodland through stages of forest succession. As suburban development commenced and resulted in land clearing for housing and roads, much of the woodland was divided into smaller woodlots.

The typical size of forestland parcels in the Basin is unusually small with 90 percent of all private holdings containing 10 acres or less, and 38 percent containing less than 5 acres. These holdings are usually considered a part of a residence by the owners. Land is generally owned for privacy, aesthetics, and recreation, rather than for income (Table III-2). The goals and objectives of most of the homeowners regarding the use of their forestland do not generally result in active forest management for the purpose of encouraging the growth of high-quality, marketable trees. As a result of these ownership objectives, commercial cutting of sawtimber and fuelwood is an infrequent use of the resource. On parcels of a somewhat larger size, landowners typically do not find it to be economical or aesthetically desirable to allow cutting.

Table III-2. Reasons for Owning Forestland in Massachusetts

Reason	Owners		Land Area	
	Number	Percent	Acres	Percent
Land Investment	17,000	16	458,900	19
Recreation	16,800	16	499,000	21
Timber Production	3,800	4	244,800	10
General Farm Use	9,300	9	289,900	12
Part of Residence	42,400	41	643,200	26
Other	14,600	14	296,500	12
Total	103,900	100	2,432,300	100

Source: Kingsley, Neal P., USDA Forest Service Resource Bulletin NE-41, 1976.

The forestland in the North and South Rivers Basin is utilized both as an aesthetic and recreational environment and to produce forest products. The primary use of the forest resource by most forest landowners, however, is categorized under the aesthetic and social goals which include enjoyment of the natural forest ecosystem, recreation, and privacy. Also related to these goals is the contribution that such an environment adds to real estate values. The importance of these ownership goals is represented by the fact that hundreds of thousands of tax dollars have been approved by the voters for use in the purchase and preservation of conservation lands. Interviews with basin residents indicate that these decisions are linked to a desire to preserve the rural appearance and atmosphere of their communities. The high value associated with living in non-urban surroundings is also illustrated by the high price of unimproved land in the Basin.

The aesthetic and recreational values of the forest resource encompasses more than these market expressions of value. Increased real estate values and increased taxation for conservation land preservation bring some of these values into the economic marketplace, but a consumer surplus remains as an additional value to residents. Consumer surplus is an economic term for the difference between the maximum amount that a consumer would pay for the perceived amenity value and the amount which the consumer actually pays. For example, if forestland were removed, some residents would occasionally drive to forested areas to experience recreation in a forest environment, a cost which is not paid due to the forestland in the Basin. Similarly, if each basin resident indicated an amount which he or she would be willing to pay to maintain trees on the forestland closest to their residence, this sum would be expected to be far greater than that portion of the value which is actually captured in market transactions. These values representing the aesthetic qualities and residential location advantages of forestland overwhelm the forest product land values simply because the value of land as a residential lot far exceeds the value of the same lot if used solely for the production of wood products. Current stumpage fees of $8 to $12 per cord on land containing roughly 10 to 20 cords per acre of merchantable growing stock do not produce a competitive return to the landowner if the harvesting is perceived as lowering the aesthetic value of the land.

The major forest products produced in the North and South Rivers Basin are firewood and sawtimber. The industrial fuelwood use in Plymouth County is neglible at the present time.* The harvest of forest products in the North and South Rivers Basin are in response to fiber and energy demands and are presently estimated to be 25,200 cords (Table III-3).

Table III-3. Annual Harvest from North and South Rivers Basin Forestlands, 1980

Harvest by use	Volume harvested	Portion of harvest
	cords	percent
Fuelwood locally cut 1/	19,200	76
Sawtimber 2/	6,000	24
Total	25,200	100

1/ Computed from data collected in Massachusetts as part of the New England Fuelwood Study.

2/ Volume of sawtimber converted from board feet at 500 board feet per cord.

*The Massachusetts Executive Office of Energy Resources has noted the absence of industrial fuelwood use in Plymouth County. This is confirmed by the recent research of Dartmouth's Thayer School of Engineering. Their Survey of Industrial Wood-Fired Boilers in New England: Analysis of Response, by Jeff Nadherny did not find any wood-fired boilers in Plymouth County.

The production of sawtimber in the River Basin is estimated from information provided by the Massachusetts Department of Environmental Management. Sawtimber production at local mills is in the range of 1750-4247 thousand board feet (mbf) per year. This gives an average figure of 3000 mbf per year which is probably conservative since some trees harvested locally are sawn at larger mills outside the River Basin. For example, nearby North Carver Pine saws as much as 15 million board feet per year.

Historically, production of pulpwood in Plymouth County was estimated to be 11,400 cords (46 percent softwood, remainder hardwood), with approximately 6,000 cords being harvested in the basin towns.* Presently, however, with the economic demise of pulp mills located within reasonable transportation distances from the Basin, no pulpwood is presently being harvested.

Resources managers should be cognizant of the intensive demands on the forest resources in the Basin, and of the physical, institutional, social, and economic constraints that influence supply. Particular influences that will affect the future forest resource supply and demand relationships are goals and objectives of forest owners and users, forest conditions, cordwood and other wood product prices, and prices of conventional fuels. The influences of all of these factors should be considered in evaluating the potential actual sustainable yields.

The aesthetic and social uses of forestland in the River Basin overshadows the commercially productive uses of the forest resource. Interviews with residents found a general opinion that landowners are not attracted by the potential stumpage value of their resource because their relative affluence and the small size of their woodlots make potential earnings insignificant. Despite this widely held view, significant numbers of trees are being harvested each year from the Basin for residential fuelwood.

RESIDENTIAL FUELWOOD USE

The use of wood for energy has increased dramatically in Massachusetts since the 1973 oil embargo due primarily to increases in price and uncertainty of supply of conventional fuels. As a result a transition to wood energy as a substitution for conventional fuels has occurred. The extent and nature of residential wood energy use in the North and South Rivers Basin was estimated through a wood energy survey conducted in Massachusetts as part of the New England Fuelwood Study.** The survey was the first step towards understanding the impacts and possible consequences upon the forest resource base resulting from the residential transition to wood use.

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* Nevel, Robert Jr., and David Dickson, Northeastern Pulpwood, 1977. USDA Forest Service Resource Bulletin NE-60, 1979.

** The New England Fuelwood Study incorporated a cooperative survey effort involving federal, state, and local agencies throughout the six-state area. The study was conducted by the Economic Research Service of the U.S. Department of Agriculture. Reports by Mark R. Bailey and Paul R. Wheeling, Economic Research Service, USDA, on the residential use of wood energy in each of the New England states are presently being published.

The transition to residential use of wood energy is illustrated by the increased use of airtight wood stoves. Eighteeen percent of all homeowners in the River Basin used a wood stove during the winter of 1978-79, compared with 15 percent in Massachusetts and 21 percent in all of New England (Table III-4). Airtight wood stove users in Massachusetts burn about three cords of wood during a winter and report large savings in their fuel bills. An additional 23 percent of homeowners in the River Basin burn wood in fireplaces. Fireplaces are inefficient, in that they provide relatively little available heat. Less wood is burned, on average, in these apparatuses, primarily because they are used for aesthetic reasons.

Table III-4. Use of Wood Burning Equipment by Homeowners in the North and South Rivers Basin, 1979

Apparatus Used	Percent of Households
Non-wood burning	58
Open fireplace	18
Efficient fireplace	5
Traditional wood stove	5
Airtight wood stove	13
Central wood-fired heating	1

The average fireplace-burner in Plymouth County uses about one cord of wood per year, while the average stove or wood furnace burner uses about 3 cords. The latter figure is slightly below the Massachusetts average of 3.4 cords per heating season. This may be attributed to a number of factors, including a smaller average size of woodlot for self-cutting, relatively high price of purchased wood, a more temperate coastal climate, and higher average income.* Many homes are relatively new, and may have better than average insulation and other energy saving features.

The annual residential use of cordwood in the eight River Basin towns is more than 19,000 cords (Table III-5). The estimate is based upon a sample of 320 household interviews covering the five coastal counties of Massachusetts (exclusive of Boston and the Islands). These coastal counties share many important social and ecological characteristics, and the survey information indicates that they also share patterns of residential wood use. The towns of the River Basin contained approximately 31,300 occupied housing units in 1978, and 23,000 were owner occupied. In 1976, residential wood use was limited to fireplace use similar to that determined by the survey. The pattern of growth over the three-winter period surveyed in Massachusetts and the four-winter period surveyed in northern New England suggests the current trend (Figure III-1). Considering the lowered rate of wood stove sales during 1980 (as reported by retailers throughout New England) and the installation rates since 1973, residential cordwood is conservatively estimated to have increased by 20 to 30 percent since the winter of 1978-79, which results in 24,000 cords of fuelwood being burned during the 1980-81 winter.

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* Residential cordwood use has been successfully correlated to social and environmental factors as reported in an unpublished paper by Carolyn Harper, Regression Analysis of Wood Stove Installation. May, 1981.

Table III-5. Wood Burned by Residents, North and South Rivers Basin, Winter, 1978-79.

Town	Wood Burned	Portion of Total
	Cords 1/	Percent
Marshfield	4,300	22
Scituate	3,600	19
Rockland	2,700	14
Pembroke	2,200	11
Duxbury	2,100	11
Hanover	1,700	9
Hanson	1,400	7
Norwell	1,400	7
Total	19,400	100

1/ Rounded to nearest 100 cords.

Source: Computed from household survey data collected for the Massachusetts Fuelwood Study.

As is the case throughout New England, the bulk of residential fuelwood is burned by owner occupant households. In Plymouth County, homeowners occupy 68 percent of all households, and burn 89 percent of total fuelwood. Renters burn only 3 percent, and the remaining 8 percent is consumed in seasonal homes.

Families obtain their firewood by harvesting it themselves, purchasing the firewood, and/or using a combination of these. Sixty percent of the wood obtained by households in the River Basin was cut by family members, usually on their own land; the remaining 40 percent was purchased.

Presently, it is not possible to accurately trace the wood purchased by households back to its geographic origin. However, based upon discussions with residents and foresters, together with knowledge of the general cordwood shipment patterns throughout New England, and the costs per cord of wood, it is estimated that approximately half the wood sold to the River Basin residents is imported from outside the area.

POTENTIAL FUELWOOD SUPPLY

The demand for firewood is by far the largest physically consumptive use of the forest resources within the Basin. Questions have been raised as to what long-term effects may result from cordwood demand, and for that reason, an analysis of how many cords of firewood the Basin could potentially supply on a sustainable basis was conducted. The analysis was limited to hardwood since this form of firewood is by far the most preferred type demanded by the families in the Basin. The analysis assumed that a portion of the volume cut would be directly for firewood consumption, and the remainder would be from utilizing that which is left over from logging and from timber stand improvement (TSI) measures (culling operations, thinnings, etc.). Estimates are therefore provided on the supply of hardwood for fuel from two sources:

(1) those trees that should be felled and removed to improve the quality and increase the growth rate on the remaining trees, and (2) the tops and branches of sawtimber-sized trees (11 inches plus in. diameter at 4 1/2 feet above ground level) felled for a roundwood product such as logs. Firewood that would be available from TSI measures is estimated to be between 2 1/2 - 6 cords per acre. The lower figure is for those stands with shorter hardwood trees and those trees in a softwood/hardwood mixture; the larger figure is for taller hardwood trees and those trees in a hardwood/softwood mixture. Firewood available from the residual of hardwood timber harvesting operations is estimated to be between 3.2 and 6.4 cords per acre. The range of cords is due to differences in board foot volumes in hardwood sawtimber trees per acre. Additionally, there are differences in the degree of utilization and the varying sizes of branches and tops according to hardwood species and their age.

A detailed estimate of the physical fuelwood supply from these two sources would require on-site investigations of individual land holdings. The method used here is based on the mapping done by MacConnell*, and on an updated land use map developed by SCS. MacConnell estimated the forested acreages for each of the eight towns by hardwoods, softwoods, hardwood/softwood mix and softwood/hardwood mix and by height and density classes. The 1980 land use map was used to update the 1970 MacConnell acreage counts.

The analysis suggests that if all the low quality trees were removed under a Basin-wide TSI operation, and if sawtimber harvesting residue (tops and branches), then 200,000 cords would be available (Table III-6). However, this yield assumes that thousands of individual landowners would agree to TSI at the same point in time. This assumption is admittedly unrealistic.

Table III-6. Fuelwood Potential in Hardwood Thinnings, Hardwood Sawtimber Tree Tops and Branches.

Type Stand	Acres	Total Cords
Hardwood only	3,260	17,372
Mixed	4,556	17,695
Total thinnings	7,816	35,967
Hardwood only	13,090	84,299
Mixed	24,979	79,846
Total sawtimber tops and branches	37,887	164,145
Total potential fuelwood	45,703	199,212

Note: The above figures describe a theoretical, one-time harvest which would be possible only if every landowner chose actively to manage his acreage for fuelwood and sawtimber production. In reality, only a fraction of total forested land is available for cutting.

* MacConnell, William P., Remote Sensing 20 Years of Change in Plymouth County, Massachusetts, 1951-1971. Cooperative Extension Service, University of Massachusetts, Pub. No. 95, December 1973.

such a thinning operation would enhance the annual production capability of that acre. After such a thinning operation, given the productivity of the soils, the climate and the species that abound, somewhat less than one cord an acre per year can be expected. Thus, a typical user of an airtight stove would need approximately 4 to 6 acres to supply the desired 3 to 4 cords per year on a sustainable year basis. However, given the fact that many users of cordwood purchase some portion of the wood they burn, it is conceivable that 2 acres would supply an adequate amount of cordwood. It should be emphasized that the way in which such cutting is managed is extremely important to an adequate long-run sustainable harvest. Where planning is absent, there is a noted tendency for woodburners to begin cutting those trees that are easily accessible from nearby roads or the house, regardless of the future productive potential of such trees.

Small parcel development and sale of sawtimber may be feasible only through membership in a landowner cooperative. Such groups, which are being organized by the Extension Forester in Hanson, link nearby parcels together for forest management purposes, making it economically possible for commercial forest harvesters to operate when the timber matures.

In any case, management information is available to the small forestland owner from a number of sources: State service foresters, Extension Service agents, or consulting foresters. Town conservation commissions can usually refer forestland owners to the appropriate information source. In addition, the Office of the Chief Forester, Massachusetts Department of Environmental Management (DEM), may be contacted. This office, in cooperation with USDA's Forest Service, provides the primary assistance delivery program to the small woodlot owner through the DEM Service Forester located at the Myles Standish State Forest.

Conservation lands and town-owned lands appear to offer a good potential for improved management and increased productivity. Whereas most private holdings are relatively small in size, usually less than 5 acres, public lands are commonly in parcels of tens or hundreds of acres. With acreages of this size, a coherent plan of forest management becomes practical. Local sawmills have recently been allowed to cut timber on some public lands with positive results. In poorer quality stands, which require substantial thinning, increased demand for wood energy has opened the possibility of towns selling stumpage to commercial cordwood dealers. Under proper management controls, the quality of publicly-owned forests can be improved while simultaneously providing economic benefits to the community.

In the North and South Rivers Basin, hundreds of acres of forestland are owned publicly, the bulk of it being conservation land. To date, active management for fuel and forest products has been limited in most towns. However, there are indications that this situation may be changing. For example, an Agricultural Extension Service survey in Hanson indicated that there was clear public support for forest management on town lands, and fuelwood and sawtimber harvesting are now planned. In Duxbury, a detailed management plan has been developed by Conservationist Ed Leary for 123 acres of conservation land known as Trout Farm. Further, several towns plan to undertake a more active management program in coming years.

In conclusion, properly designed forest management measures can assist in the attainment of a multitude of forestland ownership objectives while offering secondary benefits that do not detract from ownership goals or objectives.

A more realistic estimate can be formulated. Since 38 percent of the Basin's forestland area is in relatively small tracts, which are usually considered a part of the residence by homeowners, this area would, in all probability, contribute little cordwood. Of the remaining 62 percent of the area, approximately half is wetland where minimal harvesting takes place; hence, approximately 31 percent of the area remains for cordwood harvesting. Thus, if it is assumed that the harvesting time is for a 10-year period, then the available supply is 6200 cords per year (.31 x 200,000 cord potential/10 years = 6200 cords) that would be available for purchase by those who purchase all or a portion of their fuelwood. While the 6200 cord estimate does not include the total biomass that would be present if all the wood were used, it provides a comparison with the present 4800 cords of firewood presently being cut and made available for sale in the Basin.

FOREST MANAGEMENT ALTERNATIVES

The 46,000 acres of woodland in the North and South Rivers Basin are a resource of great value to the thousands of private landowners and their communities. The most visible and highly valued benefits are those associated with aesthetic demands--natural beauty, privacy, and recreation. A group of secondary benefits, less well known but nevertheless of considerable importance, are fuelwood for home heating and wood products such as sawtimber, boxwood, and pulp. These values together with individual ownership goals and objectives define the relevant forestland management practices that may be employed in the Basin.

Alternative forest management techniques can be developed for any number of goals and objectives. The key to adopting appropriate forest management strategies is to attain as many forestland uses as possible while still meeting the forestland owners' goals and objectives. For example, an owner wishing to harvest his forestland acreage with minimal negative impact on the land resource can do so by developing a detailed harvesting plan and by developing and maintaining properly constructed and located forest roads (assistance in doing this is available from the Plymouth County Service Forester with the Massachusetts Department of Environmental Management, Myles Standish State Forest, Box 66, S. Carver, MA 02566). Another owner who wishes to maximize wildlife habitat can selectively cut certain trees (or patch cut) and follow up by planting trees and shrubs known to provide food and shelter for the desired species of wildlife.

It should be noted that performing TSI operations is not necessarily in opposition to the aesthetic goals of many of the Basin's forestland owners. TSI measures that improve the quality of the forestland stand include but are not limited to the following:

> Weeding young stands to remove unwanted species and make more room for higher value trees.
>
> Thinning to relieve overcrowding and thus increase the growth rate of potentially more valuable crop trees.
>
> Release of vigorous young potential crop trees for faster growth and better quality by removing overtopping trees.

Cull tree removal to make available growing space occuped by deformed or defective trees that are not marketable.

Sanitation cutting to remove trees that harbor insects or diseases for the protection of the remaining stand.

TSI operations and selective cutting can improve the aesthetic values of forestland. Good quality selective cutting improves growth and furthers the development of marketable trees for the future. In addition, thinning provides aesthetic benefits as well as improving the quality of the stand. A visual survey conducted by Robert Bush demonstrates that stands which have been thinned and pruned are more pleasing aesthetically: "With harvesting operations, the stand structures of managed stands were perceived to be more attractive than untreated, fully stocked stands of similar forest types."* Similar results were obtained by the Soil Conservation Service in a visual survey specific to the River Basin.

Many owners feel that the benefits from observing the beauty of a forest exceed all others. Although aesthetic benefits are available without extra management efforts, they can be increased by adopting appropriate management practices. Conifers may be planted in hardwood stands to give green color in winter; flowering shrubs and trees may be released from competition of large trees by thinning such trees and vistas may be opened by cutting groups of trees. In addition to the aesthetic values associated with forestland, there are many miscellaneous benefits, pleasures, and products available to woodlot owners. Some common ones are wild mushroom gathering, observing and picking wildflowers, birdwatching, and herb gathering.

In terms of conventional forest management, there are a number of constraints that face an area like the North and South Rivers Basin. Of a total of 46,000 forested acres, only a fraction is owned in parcels considered "economically large enough to manage." Foresters often state that 10 acres is the minimum size for which forest management is practical. It is also the minimum amount of forestland which can be registered for tax incentives in Massachusetts under Chapter 61, the Farmland Assessment Act.

The very small parcel owner, however, may not be familiar with the sources of relevant forestry information and advice. This may be one reason why most owners formulate no coherent plan for their land. The results of the New England Fuelwood Study indicate that a relatively large amount of firewood cutting is occurring on residential lots of very small size. A question arises as to the appropriate method of selective cutting that will provide adequate supplies of fuelwood to those families who own 2 to 10 acres of woodland and who desire a small but consistent supply of fuelwood over time for their wood burning equipment. Thus, an extremely important question that needs answering is how much can a "typical" acre of woodland in the Basin supply in the form of cordwood. A previously unmanaged, overstocked acre of woodland will obviously benefit from a major thinning, in terms of improving the aesthetics, wildlife habitat, as well as providing between 5-15 cords of firewood depending upon the density and the maturity of the stand. Properly conducted,

---

* Bush, Robert, "The Attractiveness of Woodlands: Perceptions of Forest Landowners in Massachusetts," Forest Science, Vol. 25, No. 3.

Appendix IV

WATER SUPPLY PLANNING DATA

Introduction

The Water Resource Management Planning Regulations adopted by the Massachusetts Water Resources Commission (MWRC) are intended to facilitate the development of comprehensive water resources management plans that are based on local, regional, and state assessments of water needs and water resources in conformance with the Massachusetts Water Supply Policy. The plans should provide a basis for state and federal action and support and assist in the provision of legitimate local needs for water supply, recreation, waste disposal, and other water related uses.

The MWRC is mandated to prepare and update a State Water Resource Management Plan that includes each river basin in Massachusetts. The plan is to be based on local 5-year plans submitted by municipalities, and studies prepared by regional planning agencies, state agencies, the New England River Basins Commission, and federal agencies. Plans developed shall be considered by state agencies in all decisions relating to water resources management, including allocation of resources, expenditures of funds, and the making of legislative recommendations affecting policies and programs. No final decisions contrary to the plans should be finally made without the concurrence of the MWRC and no proposed actions contrary to the plans will be endorsed by the MWRC.

This Appendix presents the results of an analysis of the municipal water supply situation in the North and South Rivers Basin including the towns of Duxbury, Hanover, Hanson, Marshfield, Norwell, Pembroke, Rockland, and Scituate. Basic data were obtained through interviews with water department officials and from survey forms completed by water department superintendents under requirements of the state's Municipal Water Resources Management Plan in addition to previous studies completed by consultants and state and federal agencies. The data, conclusions, and alternatives presented will be useful in the development of the water resources management plan for this basin.

This Appendix also presents the results of an analysis of the groundwater resources in the North and South Rivers Basin that will be helpful in assessing the resources and developing aquifer protection guidelines. Data for the evaluations were assembled by USDA Soil Conservation Service personnel or were obtained from interviews with water department officials, consultants, drilling firms, and U.S. Geological Survey personnel. The Bibliography includes all the reports and maps used in the preparation of the groundwater analysis.

A series of maps has been prepared to present the results of the groundwater investigations.

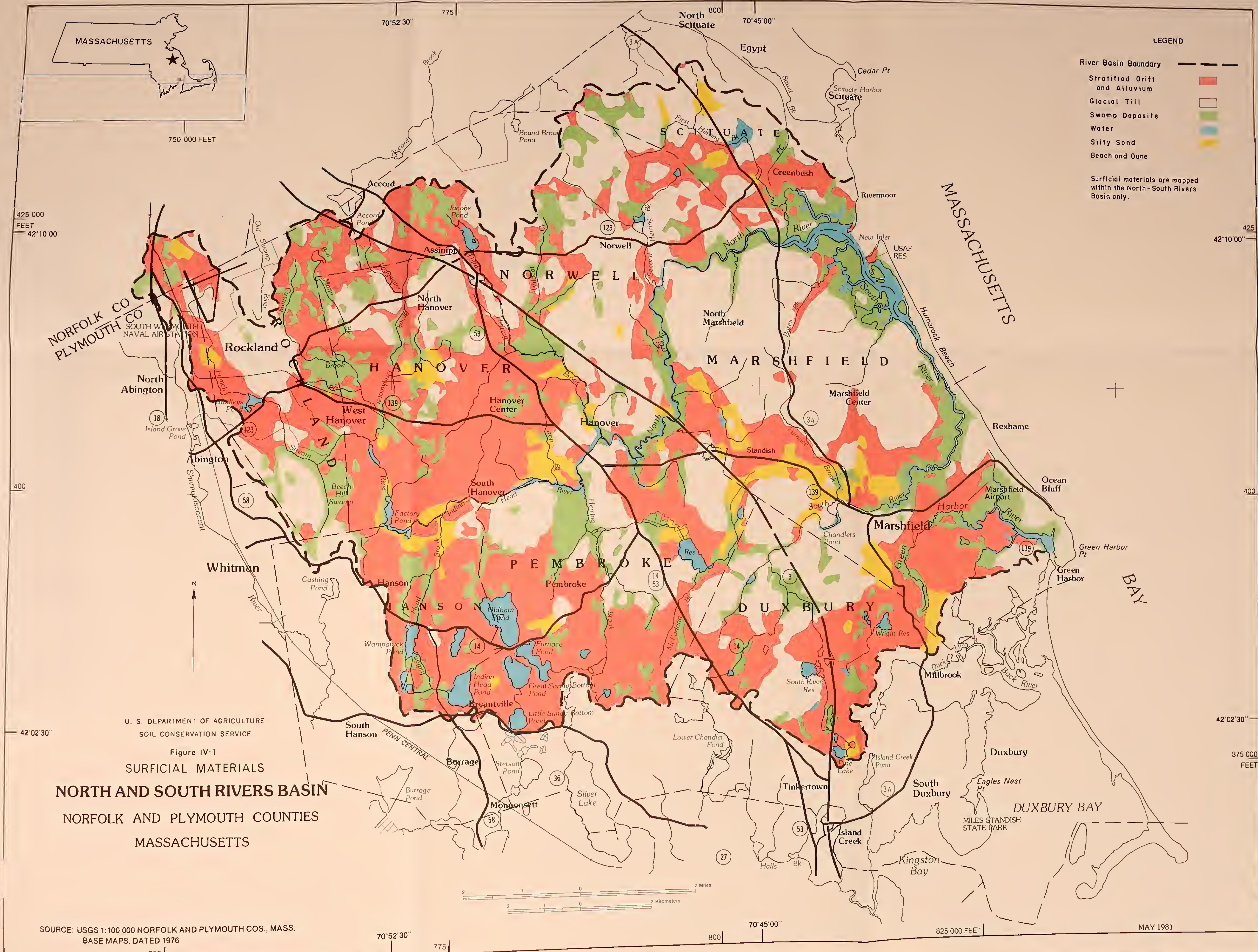
Figure IV-1, Surficial Materials Map, is an interpretive map compiled from several sources with U.S. Geological Survey Maps used to delineate geologic units according to their recharge capabilities.

Figure 2, Watersheds Map, indicates the surface watersheds. In New England, generally, surface water divides are coincident with groundwater divides. However, in large areas of low relief topography or kettle and kame topography, such as the North and South Basin, the surface watershed may not be totally reflective of the groundwater boundaries. Groundwater underflow is known to occur in such cases. For example, seasonal fluctuations, cranberry pond pumpage, and municipal pumpage near watershed boundaries all influence the flow of groundwater and may cause interbasin underflow. Mathematical analysis of groundwater aquifers made in this study assume that the two boundaries are coincident realizing the inherent limitations in the methodology.

Figure 3, Well Watersheds Map, indicates the surface watershed for municipal wells. In addition, this map indicates areas identified to have potential yields over 100 gallons per minute for wells completed in stratified deposits.

Figure 4, Potential Groundwater Hazard Map, indicates the location of landfills, dumps, salt storage piles, and underground gasoline storage tanks. Locations of dumps and landfills were determined in the field. Locations of underground gasoline storage tanks were determined from local records but were not field checked. The locations of dumps, landfills, and salt storage piles may not be a complete listing.

Figure 5, Recharge Capabilities Map, is an interpretive map based on soil survey information. Soils are placed in groups based on permeability. Soil permeability as shown on the map is generally a field estimate based on the experience of the soil scientists and comparison with laboratory data on selected soils. The soils most likely to act as primary recharge areas are those with the highest permeability. Those with lower permeability rates will tend to inhibit infiltration and are, therefore, not as highly rated for recharge capability.

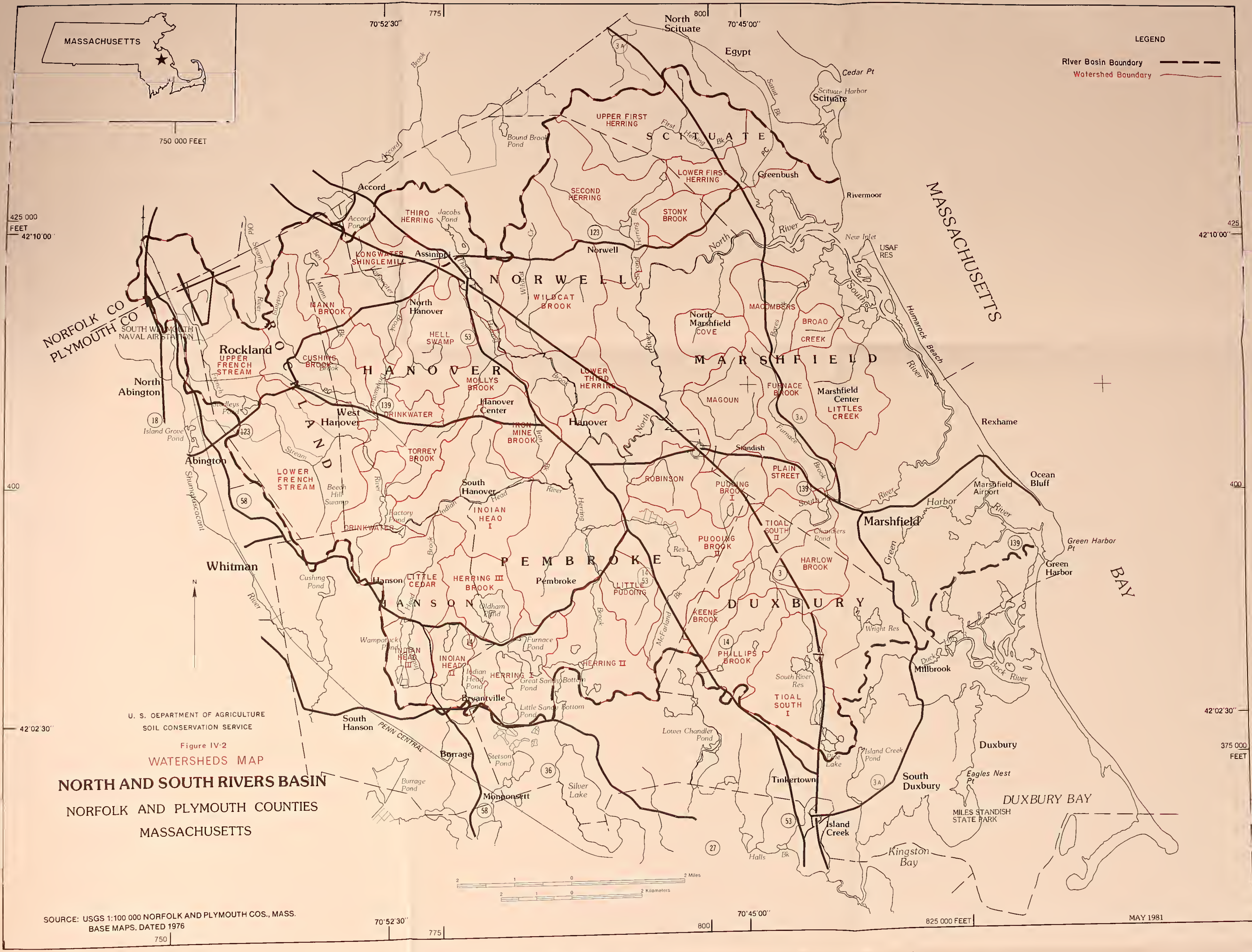


U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Figure IV-1
SURFICIAL MATERIALS

NORTH AND SOUTH RIVERS BASIN

NORFOLK AND PLYMOUTH COUNTIES
MASSACHUSETTS



U. S. DEPARTMENT OF AGRICULTURE
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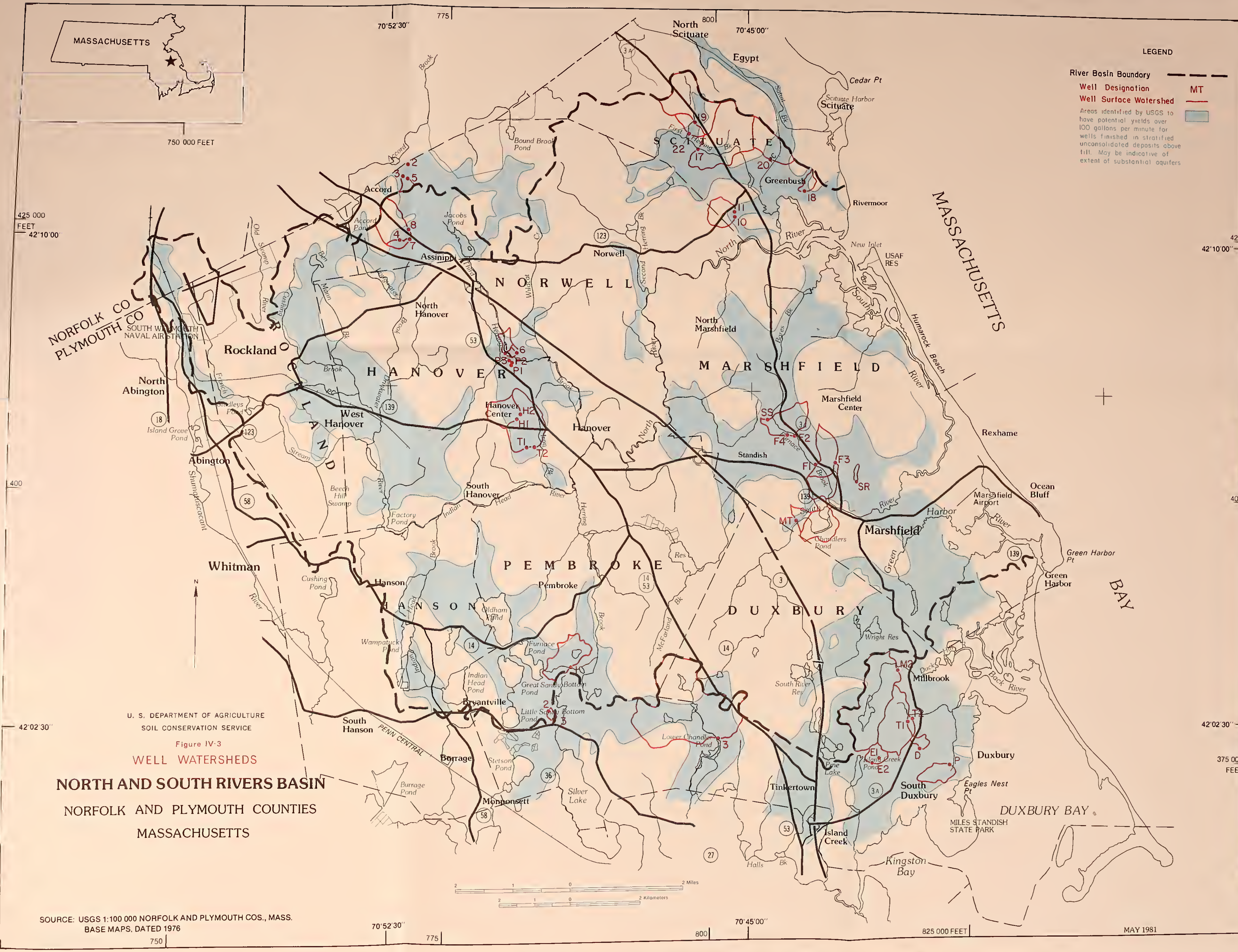
Figure IV-2
WATERSHEDS MAP
NORTH AND SOUTH RIVERS BASIN
NORFOLK AND PLYMOUTH COUNTIES
MASSACHUSETTS
LEGEND
River Basin Boundary
Watershed Boundary
MASSACHUSETTS
SOURCE: USGS 1:100 000 NORFOLK AND PLYMOUTH COS., MASS. BASE MAPS. DATED 1976
MAY 1981
NORFOLK CO
PLYMOUTH CO
MASSACHUSETTS BAY
DUXBURY BAY
SCITUATE
NORWELL
MARSHFIELD
HANOVER
ROCKLAND
PEMBROKE
HANSON
DUXBURY
UPPER FIRST HERRING
LOWER FIRST HERRING
SECOND HERRING
STONY BROOK
THIRD HERRING
LONGWATER SHINGLEMILL
WILDCAT BROOK
MANN BROOK
HELL SWAMP
CUSHING BROOK
UPPER FRENCH STREAM
MOLLYS BROOK
LOWER THIRD HERRING
DRINKWATER
IRON MINE BROOK
TORREY BROOK
LOWER FRENCH STREAM
INDIAN HEAD I
INDIAN HEAD II
INDIAN HEAD III
LITTLE CEDAR
HERRING III BROOK
HERRING I
HERRING II
LITTLE PUDDING
MACOMBERS
BROAD CREEK
NORTH MARSHFIELD COVE
MAGOUN
FURNACE BROOK
LITTLES CREEK
ROBINSON
PLAIN STREET
PUDDING BROOK I
PUDDING BROOK II
TIDAL SOUTH I
TIDAL SOUTH II
HARLOW BROOK
KEENE BROOK
PHILLIPS BROOK
North Scituate
Egypt
Cedar Pt
Scituate Harbor
Scituate
Greenbush
Rivermoor
New Inlet
USAF RES
Humarock Beach
Accord
Assinippi
Norwell
North Hanover
Rockland
SOUTH WEYMOUTH NAVAL AIR STATION
North Abington
Abington
Whitman
West Hanover
Hanover Center
Hanover
South Hanover
North Marshfield
Marshfield Center
Rexhame
Standish
Ocean Bluff
Marshfield Airport
Marshfield
Green Harbor Pt
Green Harbor
Pembroke
Hanson
Bryantville
South Hanson
Burrage
Monponsett
Silver Lake
Tinkertown
Island Creek
Millbrook
Duxbury
South Duxbury
Eagles Nest Pt
MILES STANDISH STATE PARK
Kingston Bay
PENN CENTRAL
70°52'30"
70°45'00"
42°10'00"
42°02'30"
750 000 FEET
825 000 FEET
375 000 FEET
425 000 FEET
2 Miles
2 Kilometers



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SOIL CONSERVATION SERVICE

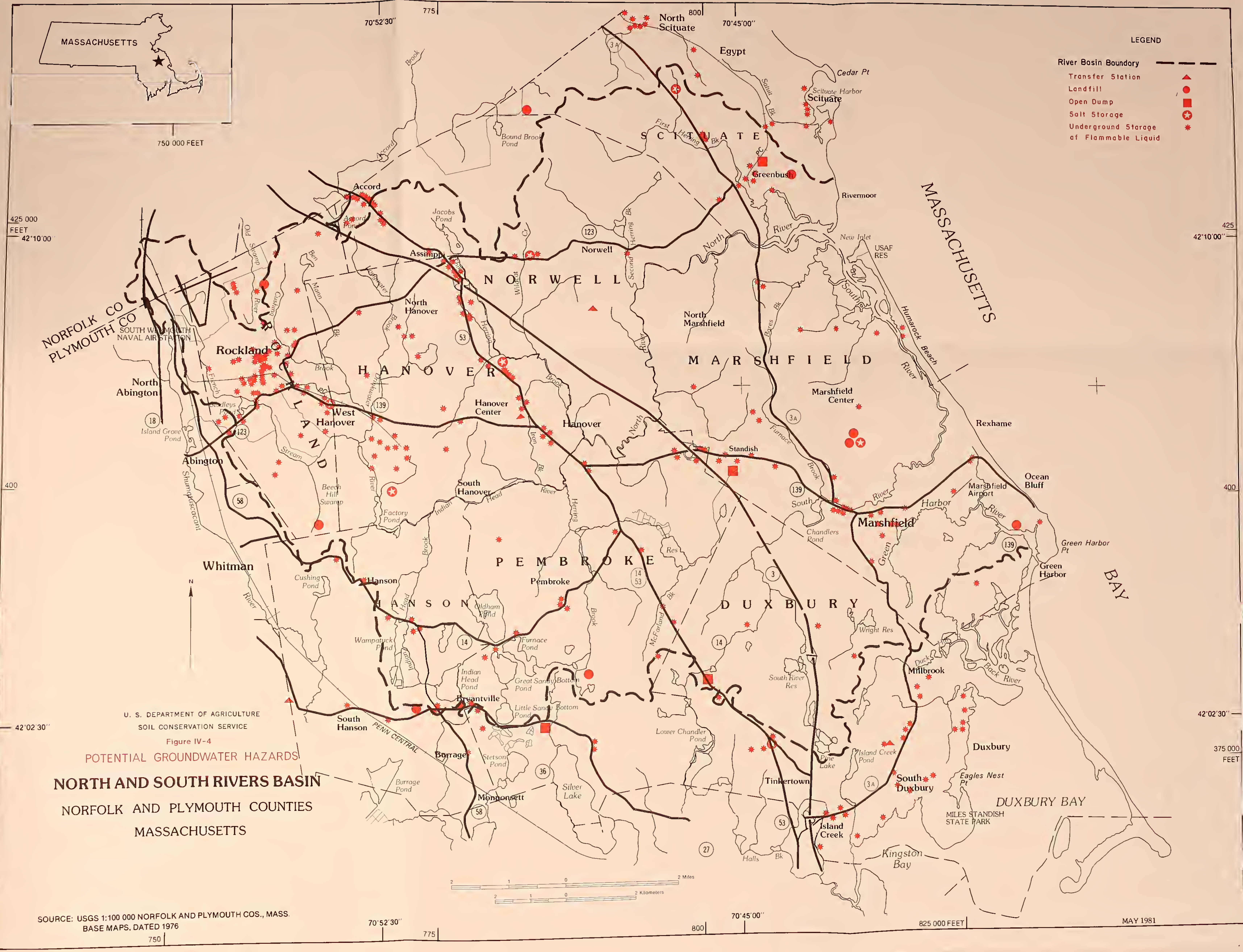
Figure IV-3

WELL WATERSHEDS

NORTH AND SOUTH RIVERS BASIN

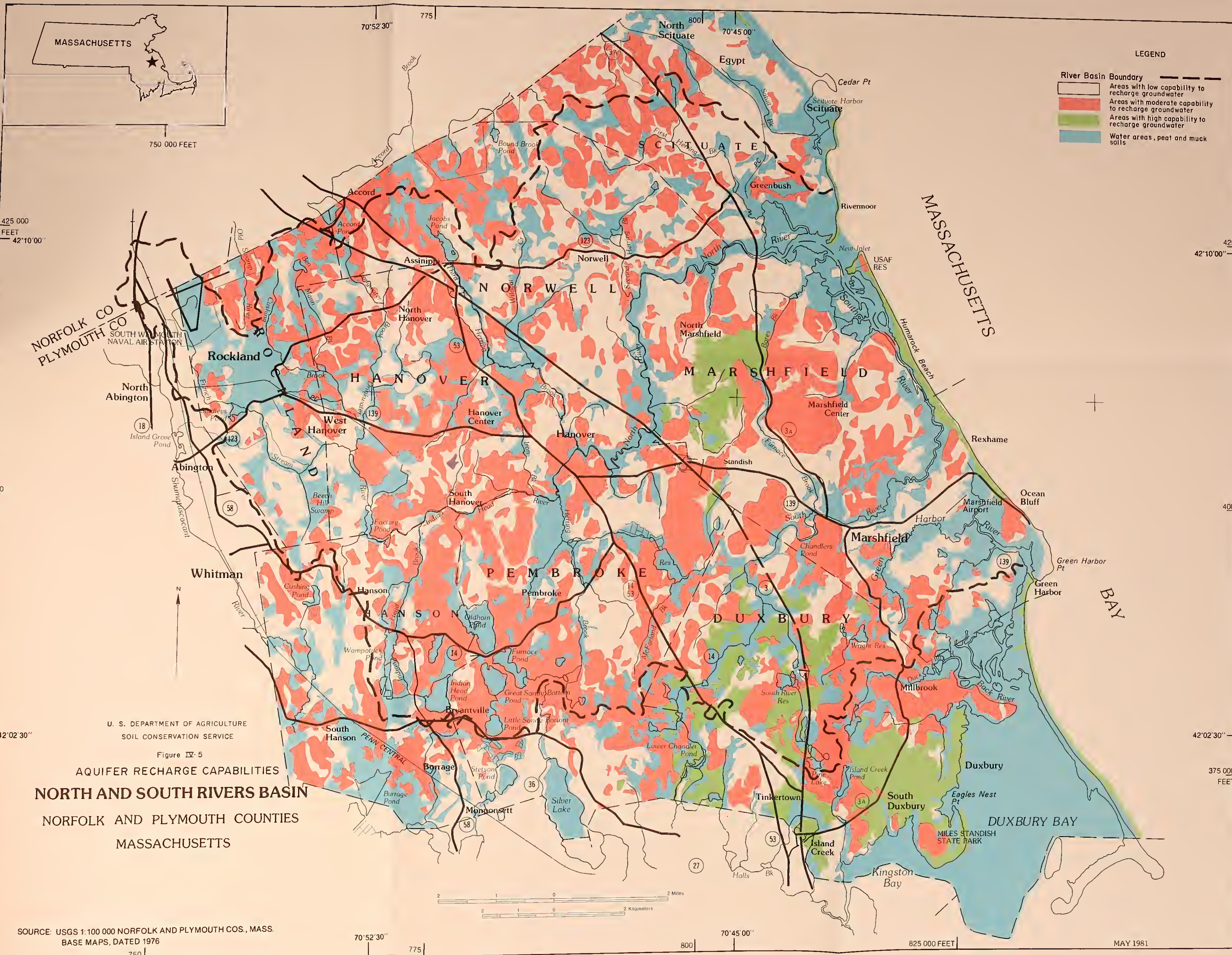
NORFOLK AND PLYMOUTH COUNTIES

MASSACHUSETTS



U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Figure IV-4
POTENTIAL GROUNDWATER HAZARDS
NORTH AND SOUTH RIVERS BASIN
NORFOLK AND PLYMOUTH COUNTIES
MASSACHUSETTS

SOURCE: USGS 1:100 000 NORFOLK AND PLYMOUTH COS., MASS. BASE MAPS, DATED 1976



U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Figure IV-5

AQUIFER RECHARGE CAPABILITIES

NORTH AND SOUTH RIVERS BASIN

NORFOLK AND PLYMOUTH COUNTIES

MASSACHUSETTS

Estimated Long-Term Yields

Table IV-1 presents estimates of long-term yield from watersheds using a modification of the procedure in the U.S. Geological Survey publication, "Water Resources Inventory of Conn., Part 8, Quinnipiac River Basin, Mazzaferro et al. 1979."

For each watershed indicated, the areas of glacial till, silty and swampy soils, and stratified drift were identified and the percent of the area underlain by stratified drift calculated. The groundwater outflow was calculated as a percent of the mean annual runoff using a linear regression formula developed by USGS based on the data of 28 basins in New England with geologic characteristics similar to those in the North and South Rivers Basin. The mean runoff from each watershed was determined by using a value of runoff in the North and South Rivers Basin of 2.00 cubic feet per second (cfs) per sq. mi. or 1.29 million gallons per day (mgd) per sq. mi.

The average annual groundwater outflow and the groundwater outflow equaled or exceeded 7 years out of 10 was calculated. Seventy-five percent of this value was estimated to be available for capture by municipal wells.

The 90 percent duration flow of the stream which is in hydrologic contact with the aquifer was also computed assuming that drying up the stream by induced infiltration more than 10 percent of the time is undesirable. The flow duration chart used to arrive at this figure is from Mazzaferro et al. (1978). The chart underestimates streamflows since it is based on a mean annual flow of 1.80 cfsm whereas the North and South Rivers Basin is more nearly equal to 2.0 cfsm.

The estimated maxiumum amount of water available over a long-term period in million gallons per day is provided in Table IV-1. Where induced recharge from streams is not likely, only the 7 out of 10 year groundwater outflow is available to wells. Estimates of water available assume a well would be located at the discharge or furthest downstream point in the watershed.

It should be noted that an anlysis of this nature can be quite accurate in areas where groundwater and surface water watersheds are coincident. In some areas of the North and South Rivers Basin where the groundwater watershed is much more extensive than the surface watershed, these estimates of long-term yield can be considered to be extremely conservative and actual yields will be higher than those indicated in Table VI-1.

Table IV-1

Estimated Long-term Yields 2/ From Favorable Groundwater Areas

Watershed	Watershed Area (Sq. Mi.)	Percent of Area Underlain by Stratified Drift	Groundwater Outflow Equaled or Exceeded 7 Years in 10 (MGD)	Flow of Principal Streams Entering Favorable Area Equaled or Exceeded 90% of the Time (MGD)	Estimated Maximum Amount of Water Available Over a Long Time Period 1/ (MGD)
Upper First Herring	4.0	11	2.9	0.4	2.6
Lower First Herring	1.5	21	1.1	0.3	1.1
Second Herring	3.7	53	2.7	1.6	3.6
Third Herring	2.8	50	2.1	1.1	2.7
Molly's Brook	1.3	86	0.9	0.8	1.5
Wildcat Brook	4.1	17	3.0	0.7	3.0
Lower Third Herring Brook	2.2	44	1.6	0.8	2.0
Magoun	1.9	37	1.4	0.6	1.7
Pudding Brook	1.2	22	0.9	0.2	0.9
Pudding Brook	3.5	34	2.6	1.0	3.0
Herring I	2.2	75	1.7	1.3	2.6
Herring II	2.3	79	1.7	1.4	2.7
Herring III	1.7	71	1.2	0.9	1.8
Upper French Stream	4.2	46	3.1	1.6	3.9

Watershed	Watershed Area (Sq. Mi.)	Percent of Area Underlain by Stratified Drift	Groundwater Outflow Equaled or Exceeded 7 Years in 10 (MGD)	Flow of Principal Streams Entering Favorable Area Equaled or Exceeded 90% of the Time (MGD)	Estimated Maximum Amount of Water Available Over a Long Time Period (MGD) 1/
Lower French Stream	4.8	42	3.5	1.8	4.4
Cushing Brook	2.9	53	2.2	1.2	2.9
Mann Brook	1.7	41	1.2	0.6	1.5
Longwater Shinglemill	2.6	56	1.9	1.2	2.6
Hell Swamp	2.4	36	1.8	0.8	2.2
Drinkwater	1.7	77	1.3	1.0	2.0
Torrey Brook	1.0	80	0.8	0.6	1.2
Drinkwater	1.5	73	1.1	0.9	1.7
Indian Head III	1.2	50	0.9	0.5	1.2
Little Cedar	2.1	62	1.5	1.0	2.1
Indian Head I	3.3	68	2.4	1.9	3.7
Indian Head 2	1.2	71	0.9	0.7	1.4
Macombers	1.6	7	1.1	0.1	0.9
Furnace	1.4	9	1.1	0.1	0.9
Phillips	1.8	49	1.3	0.7	1.7
Tidal South II-V	1.9	3	1.4	0.1	1.1
Cove	1.0	0	0.7	0	0.5

Table IV-1 (continued)

Watershed	Watershed Area (Sq. Mi.)	Percent of Area Underlain by Stratified Drift	Groundwater Outflow Equaled or Exceeded 7 Years in 10 (MGD)	Flow of Principal Streams Entering Favorable Area Equaled or Exceeded 90% of the Time (MGD)	Estimated Maximum Amount of Water Available Over a Long Time Period 1/ (MGD)
Little Creek	2.1	19	1.5	0.4	1.5
Iron Mine	1.3	56	1.0	0.6	1.4
Harlow Brook	1.1	0	0.8	0	0.6
Broad Creek	0.6	67	0.4	0.3	0.6
Plain St.	0.7	79	0.5	0.5	0.9
Robinson	1.1	0	0.8	0	0.6
Keene Brook	1.0	30	0.7	0.3	0.8
Little Pudding	1.0	17	0.8	0.2	0.8
Stony Brook	0.8	15	0.6	0.1	0.6
Tidal South	2.9	51	2.2	1.2	2.9

Procedure modified from USGS Methodology in "Water Resources Inventory of Connecticut, Part 8 - Quinnipiac River Basin, Mazzaferro, et al., 1979. U.S. Geological Survey."

1/ Equivalent to stream flow equaled or exceeded 90 percent of the time plus 75 percent of groundwater outflow equaled or exceeded 7 years in 10.

2/ An analysis of this nature can be quite accurate in areas where groundwater and surface water watersheds are coincident. In some areas of the North and South Rivers Basin where the groundwater watershed is much more extensive than the surface watershed, these estimates of long-term yield can be considered to be extremely conservative and actual yields will be higher than those indicated.

Community Analyses

Information for each community is presented in the following areas:

1. PRESENT CONDITIONS - This section has data on population served in each town, developed water supply sources, system safe yield, water quality problems, water treatment measures, and conservation measures undertaken by the town.

2. PROJECTIONS - Projections of future demand are presented in this section for the years 1990, 2000, 2010, and 2020. Estimates of demand for water have been computed on the assumption that per capita demand will increase at one percent per year.

3. NEEDS - This section compares projected demands with developed safe yield of the water system.

4. PREVIOUS STUDIES AND RECOMMENDATIONS - Previously identified alternatives are provided in this section. In many instances, the towns of the Basin have conducted exploration programs for new groundwater sources and have located favorable areas. This information is summarized and references to previous reports and investigations are made.

5. GROUNDWATER EVALUATION - The primary groundwater watersheds are identified in this section. Geology, potential hazards, and potential additional supplies of municipal water are discussed.

TOWN OF DUXBURY

PRESENT CONDITIONS

In 1980, the Duxbury water system served approximately 11,800 people. Population increases substantially in the summer months but an accurate estimate is not available. Approximately 98 percent of the town population is served by the Duxbury Water Department. About 200 houses in the Duxbury Beach area are served by the town of Marshfield Department of Public Works, Water and Wastewater Division. There are no large industrial or commercial water users in the Duxbury system.

The town is supplied with water from a system of eight wells. Information concerning safe yield and pumping capacity is presented in Table IV-2. System safe yield is estimated at 3.0 million gallons per day (MGD).

Table IV-2

Town of Duxbury
Water Supply Sources

Well	Safe Yield and Pump Capacity (gallons per minute)
Partridge Road	240
Depot Street	400
Lake Shore Drive	350
Millbrook #2	350
Tremont #1	400
Tremont #2	300
Evergreen #1	600
Evergreen #2	500

All wells are pumped in a constant rotation.

System safe yield is estimated at 3.0 million gallons per day based on each well being pumped at safe yield for 16 hours per day.

Water is treated with Calgon. The primary water quality problem is corrosion.

All of the current users are metered. Water is billed on a block rate structure.

PROJECTIONS

Projections of future water demand are presented in Table IV-3.

Table IV-3

Projected Water Demand

Year	Average Daily Demand (MGD)	Maximum Daily Demand (MGD) 1/
1990	1.7	4.3
2000	1.8	4.8
2010	2.1	5.4
2020	2.4	6.1

1/ Maximum daily demand is estimated to be 2.58 times average daily demand. This figure incorporates the effect of summer population increase.

NEEDS

Since the Duxbury system relies entirely on groundwater sources, the system safe yield must be able to meet the maximum daily demand. Table IV-4 summarizes the comparison of future demand and developed resources.

Table IV-4

Comparison of Demand and Supply

Year	Maximum Daily Demand (MGD)	System Safe Yield (MGD)	Needs (MGD)
1990	4.3	3.0	1.3
2000	4.8	3.0	1.8
2010	5.4	3.0	2.4
2020	6.1	3.0	3.1

PREVIOUS STUDIES AND RECOMMENDATIONS

Duxbury is included in U.S. Geological Survey Report and Hydrologic Atlas 504 and Hydrologic Data Report #16.

In 1978 and 1979, the town engaged Whitman and Howard, Consulting Engineers, to conduct an exploratory program to locate additional sources of groundwater supply. Over 100 test wells were drilled in the 1978-79 program. Between 1946 and 1979, the town drilled over 230 test wells in an effort to locate groundwater sources.

Whitman & Howard, Inc., recommended several potential areas for further exploration and development. The following sites were proposed:

1. Site 110 located south of Church Street. This site is also known as the Damon site.

2. Site 40 located north of Church Street.

3. Site 106 located off Teakettle Lane.

4. Site 2 located off Church Street near Wright Reservoir.

5. Site 112 located south of Church Street near the existing Millbrook pumping station.

6. Site 35 located near the existing Mayflower Street pumping station,

All except Site 106 are located on town-owned land. Sites 110, 40, 106, and 2 have been subjected to prolonged pumping tests.

GROUNDWATER RESOURCES

Portions of seven primary groundwater watersheds are located in Duxbury. Of these, Philips Brook, Tidal South #1, Keene Brook, Tidal South #2, and Harlow Brook are almost entirely within the town and are discussed further below. Portions of the Pudding Brook watersheds are located within Duxbury, but these watersheds are discussed in the Pembroke section of the Appendix.

Philips Brook Watershed

This watershed is 1.75 square miles in size. Philips Brook flows northeastward from Summer Street nearly two miles to where it joins the mainstem of the South River. Maximum east-west width is about one mile. Several cranberry bogs are located in the watershed. No municipal wells pump from the watershed at this time.

About 50 percent of the area's surficial deposits are glacial till. Drillhole information, where available, indicates fine grained shallow soils.

Within the watershed there are two locations of underground flammable liquid storage and one dump. Since there are no pumping wells in the watershed, the potential hazard would be to any future development of wells that might take place.

USGS (Williams and Tasker, 1974) indicates low groundwater favorability in this watershed, but the watershed should be included in any townwide groundwater study.

Tidal South 1 Watershed

The Tidal South watershed makes up the headwaters of the South River. The watershed is triangular in shape covering an area of 2.94 square miles. Route 3 passes through the entire eastern length. Several cranberry bogs are located in the watershed. No municipal wells pump from this watershed.

Surficial geology maps indicate about half of the area is covered with stratified drift or alluvium. The northern portion of the watershed is known to consist of readvancement glacial till overlying stratified sands and gravels. Ice channel fillings extend north-south along the western edge of Lorings Bogs. These deposits are very coarse grained gravels and boulders. The ice channel fillings are typically limited in depth and lateral extent. The southern portions of the watershed are made up of outwash plain and kame plain deposits of sand and gravel. Borings made by the town in recent years near Pine Lake indicate about 20 feet of fine sand and clay or gray clay. Borings reach refusal in the 20-25 foot depth range in the Pine Lake area. In this area of Duxbury the groundwater gradients are flat; groundwater and surface water divides may not be coincident.

There are no known landfills or salt sheds within this watershed. An underground flammable liquid storage is located on the northern boundary of the watershed near Dingley Cemetery. A salt storage pile is located near Tarkiln near the southern boundary of the watershed in an area of stratified sands and gravels. Another potential hazard to well development is road salting along Route 3 and accidental waste or gasoline spills on Route 3.

This watershed has moderate potential for additional supply. Major portions of the watershed have been explored for groundwater supplies. Surficial geology and borings indicate possibly favorable areas for supply. Investigations are scant where glacial till overlies sands and gravels near Lorings Bogs.

Tidal South II Watersheds

The four sub-watersheds which make up this area bound the main stem of the South River. In this reach the South River flows north and then east to Chandler's Pond before entering Massachusetts Bay. The total area of the watershed is 1.9 square miles. One municipal well field pumps from the watershed. This field is operated by Marshfield and is indicated on Figure IV-3, Well Watershed Map, as (MT).

USGS surficial geology maps indicate that about 20 percent of this watershed is composed of stratified drift. The remainder is covered with glacial till. Numerous outcrops of bedrock occur near Chandler's Pond. The South River flows on swampy soils upstream of Chandler's Pond. Stratified drift is exposed at the surface where the watershed extends into Marshfield.

One underground liquid storage was recorded downgradient from the Mt. Skirgo Well. Activities associated with Route 3 such as road salting and accidental spills pose potential hazards to downstream well fields. No landfills or salt sheds were recorded in this watershed.

Within the Duxbury part of this watershed there is low potential for additional supplies due to large areas of glacial till and shallow saturated thickness of stratified sands and gravels. In the Marshfield portion a moderate potential exists due to a greater thickness of saturated sands and gravels near the existing Mt. Skirgo well fields.

Harlow Brook Watershed

This watershed encompasses an area of 1.1 square miles. Harlow Brook flows south and then westerly to join Philips Brook. At this point the brooks combine and join the South River. Route 3 crosses the watershed near its western boundary. No municipal wells pump from this watershed.

Surficial geologic maps show the watershed to be comprised entirely of glacial till. USGS indicates the possibility of stratified deposits underlying the glacial till in about half the area. No test wells were drilled in this watershed by Whitman and Howard, Inc. Topographic and groundwater divides are likely coincident.

No locations of landfills, salt sheds or underground flammable liquid storage were found in the watershed. Accidental spills from Route 3 and road saltings would pose a hazard to the Mt. Skirgo Well in Marshfield which probably induces water from the South River.

The watershed is rated as low potential for municipal groundwater development.

Keene Brook Watershed

This watershed covers an area of about 1 square mile. Keene Brook flows northeasterly from Route 53 about 2 miles to where it joins the South River near Camp Wing. The watershed extends about 2 miles northeast-southwest and about 1 mile northwest-southeast at its widest point. No municipal wells pump from this watershed.

Surficial geologic maps show the watershed to be composed of about 30 percent stratified drift and alluvium. The hill west of Keene Brook is shown to have large areas of exposed bedrock (Shaw, Petersen, 1967). Drill hole information is very limited.

There are no known potential groundwater hazards.

Due to large amounts of glacial till and exposed bedrock, there is low groundwater potential in this watershed.

Well Watersheds of Wells T1, T2

These wells are situated in watersheds of 176 and 210 acres, respectively (see Figure IV-3) located southeast of North Hill Marsh. Well T1 (Tremont #1) pumps 400 gpm and Well T2 (Tremont #2) pumps 300 gpm.

The combined watersheds are composed of about 85 percent stratified drift and alluvium. Borings show shallow depths of sand and gravel east of North Hill Marsh that increase toward the Tremont Street Wells.

Within the watersheds there are three locations of underground gasoline storage, one salt shed, and an old town dump. These are located on Figure IV-4.

The town has identified two proposed well sites in the Town Forest Area south of North Hill Marsh. These wells are estimated to have potential to yield 480 gpm combined capacity.

Evergreen Wells Watershed (Wells E1 and E2)

The watershed for these wells is estimated at about 64 acres. Surface water flow in this area is subject to control by cranberry bog operators. The two Evergreen Wells are capable of pumping 1.056 mgd per 16-hour day if pumped simultaneously.

The entire watershed is shown on surficial geologic maps as stratified drift.

There are no known potential groundwater hazards in these well watersheds.

The wells in this watershed are high capacity gravel packed wells. Siting of another well in this small area may interfere with operation of the existing wells.

TOWN OF HANOVER

PRESENT CONDITIONS

In 1980, the Hanover water system served approximately 11,400 people. Nearly all of the town population is served by the Hanover DPW Water Division. The average daily consumption was 1.1 million gallons per day (MGD). The average use per person served was about 96 gallons per day. The DPW Division estimates that about 65 percent of the water is for domestic use, 9 percent for commercial, 2 percent industrial, 11 percent for flushing mains, 10 percent for backwashing at the water treatment plant, and 3 percent for undetected leaks. There are no significant commercial, industrial, or agricultural water users within the community which are not supplied by the Water Division.

The town is supplied with water from a system of seven wells. Developed groundwater resources have a combined safe yield of 4.2 MGD but pumping capacity is 2.9 MGD. If all wells were pumped at safe yield for 16 hours per day, safe yield would be limited to 3.2 MGD because of limited treatment plant capacity. In addition to the developed sources of water, the town is modifying its water treatment sludge handling procedures which currently account for nearly 10 percent of municipal water use. Information concerning well type, safe yield, and pumping capacity is presented in Table IV-5.

Water from the Pond Street wells is treated by full chemical coagulation, sedimentation, and filtration. Water from the Tindale #1 well is treated with chlorine and calgon while the Hanover Street #2 well water is treated with chlorine. Water quality problems include high levels of iron, manganese, color, and sodium. Color, iron, and manganese levels increase as wells are pumped closer to their safe yield figures.

All of the present users are now metered. Water is billed to users on an increasing block rate structure. The town has emphasized water conservation through a program in the elementary and junior high schools. Leak detection surveys are made every two years. Other leaks are repaired immediately upon detection. In addition, the use of water saving devices is encouraged through the use of material sent with water bills.

Table IV-5

Town of Hanover
Water Supply Sources

Well	Well Type	Safe Yield (gallons per minute)	Pump Capacity (gallons per minute)
Pond Street #1 1/	Gravel packed	850	700
Pond Street #2 1/	Gravel packed	1170	650
Pond Street #3 1/	Gravel packed	1035	800
Tindale #1 2/	Gravel packed	300	200
Tindale #2 2/	Gravel packed	350	250
Hanover St. #1 2/	Gravel walled	350	180
Hanover St. #2 2/	Gravel walled	350	220

1/ Each of the Pond Street wells is operated in rotation for two of every three weeks. Water is pumped through a water treatment plant with capacity of 2 million gallons per day.

2/ The Tindale and Hanover Street wells are operated in rotation on a daily basis.

System safe yield estimated at 2.9 million gallons per day assuming that each well is pumped 16 hours per day. If pump capacity matched safe yield of each well, 4.2 MGD could be obtained. However, since the Pond Street wells are pumped through a treatment plant with capacity of 2.0 MGD, system yield is effectively restricted to 3.2 MGD.

PROJECTIONS

Projections of future water demand are presented in Table IV-6.

Table IV-6

Projected Water Demand

Year	Average Daily Demand (MGD)	Maximum Daily Demand (MGD)
1990	1.4	2.7
2000	1.6	3.1
2010	1.7	3.4
2020	1.9	3.7

NEEDS

Since the Hanover system relies entirely on groundwater sources, the system must be able to meet the maximum daily demand. Table IV-7 summarizes the comparison of future demand and developed resources.

Table IV-7

Comparison of Demand and Supply

Year	Maximum Daily Demand (MGD)	System Safe Yield 1/ (MGD)	Needs or Surplus (MGD)
1990	2.7	3.2	0.5 surplus
2000	3.1	3.2	0.1 surplus
2010	3.4	3.2	0.2 need
2020	3.7	3.2	0.5 need

1/ Safe yield is based on wells being pumped at their safe yield for 16 hours per day producing 4.2 MGD, but treatment plant capacity limiting available safe yield to 3.2 MGD.

PREVIOUS STUDIES AND RECOMMENDATIONS

Previous reports on the groundwater resources of Hanover were prepared by SEA Consultants in conjunction with Goldberg Zoino Dunnicliff & Associates, Inc. in 1979 and by IEP in 1978. These reports will be briefly summarized.

The 1978 IEP study involved an area defined by the watersheds which contribute groundwater and surface water to the seven Hanover municipal wells. Available data were compiled and evaluated. Surficial geology was evaluated by field investigation.

An inventory of the geology of the area was performed, resulting in a series of maps showing bedrock topography, surficial geology, saturated thickness of overburden, groundwater flow, and significant groundwater areas.

The bedrock topography map shows several preglacial buried valleys in and adjacent to the town. Seven of the nine municipal wells are located in these buried valleys. Surficial geology of the area shows glaciofluvial deposits and ice contact stratified drift as the major aquifer areas. Glacial till mantles the higher topography. The groundwater flow map was developed on existing well data and elevations of ponds, streams, and wetlands.

Estimates of groundwater contribution to the municipal wells were made using groundwater outflow factors for stratified drift and till. Table IV-8 indicates groundwater contribution to the wells. Table IV-8 shows the total amount of water available over a long period of time from the watershed and includes induced recharge where wells are located favorably to induce infiltration of streamflow.

Significant groundwater areas were identified and noted by IEP.

A nitrate contamination computer model was also developed for the area. The conclusion of the model study was that the 10 mg/l drinking standard limit for nitrate nitrogen would be reached when residential density in the Third Herring Brook groundwatershed became 1271 residences per square mile. It has been recommended to town officials that residential density in the Iron Mine Brook watershed should be limited to one acre lots.

IEP also calculated loss of recharge due to residential development. Their conclusion was that since Third Herring Brook and Iron Mine Brook groundwatersheds are already under water quality stress any additional loss of recharge would serve to decrease groundwater dilutions and accelerate the decline in water quality.

Recommendations were also made to revise Board of Health requirements to limit the effects of nitrates and phosphates and to modify by-laws to maintain infiltration rates, existing total flow, and pollutant loadings no greater than if the area were developed to the suggested residential density.

SEA Consultants, Inc., in cooperation with Goldberg-Zoino, Inc., published a report in 1979 on Protection of Groundwater Supply. Goldberg-Zoino reviewed the available geology of the Route 53 area and analyzed pump test data on the wells.

Seismic surveys conducted by Weston Geophysical Engineers, Inc., indicated three locations near the southeast corner of Hanover that had potential for municipal water sources. A test well at one of these locations estimated that a minimum of 0.7 MGD could be obtained.

Table IV-8. GROUNDWATER CONTRIBUTION TO WELLS*

Watershed	Wells	Acreage	Groundwater Contribution
Iron Mine Brook	Hanover St.	241	376,000 - 282,000 gpd
Iron Mine Brook	Broadway St.	406	577,000 - 416,000 gpd
Jacobs Pond	Pond St.	1975	2,355,000 - 1,544,000
Hoop Pole Swamp	Pond St.	1034	1,120,000 - 689,000
Wildcat Brook	Pond St.	416	446,000 - 272,000
Wildcat Hill	Pond St.	718	482,000 - 167,000
Silver Brook	Pond St.	677	1,002,000 - 734,000

*IEP, 1978.

A potential surface reservoir site has been identified near Old Washington Street and Oakland Avenue. Water would be diverted from Third Herring Brook to fill a reservoir covering about 100 acres and having a capacity of about 600 million gallons. The SEA report recommended that the town develop its identified groundwater resources before considering development of the surface reservoir.

GROUNDWATER RESOURCES

Longwater-Shinglemill Watershed

This watershed covers an area of 2.58 square miles. The watershed includes portions of Hanover, Norwell, and Rockland. Route 3 crosses the watershed from northwest to southeast.

Previous reports by consultants discussed other areas in the town; however, the Longwater-Shinglemill watershed was not included. The Basin is drained by the two southeasterly flowing streams, Longwater and Shinglemill Brooks Several swamps dominate the watershed.

Geologic maps indicate about 55 percent of the area is covered by stratified drift. USGS shows saturated thickness of 20 feet in most areas of the watershed. A large area of glacial till between Shinglemill Pond and Hackett Pond divides the two individual brook watersheds. Groundwater and surface water divides probably coincide where glacial till makes the boundaries west of Shinglemill Pond and near Walnut Hill on the east side of the watershed. Borings in the watershed are located mostly in the Rockland portion. These borings drilled by the Abington-Rockland Water Board indicate mostly fine sands and gravels with clay. Generally, conditions are unsuitable for large capacity municipal wells.

No wells are located in the watershed. Norwell has three wells located near the northeast border of the watershed. Drawdowns at these wells may cause reversal of the divide between the Third Herring Watershed and the Longwater-Shinglemill watershed.

One location of underground flammable liquid storage was recorded in the watershed. Any potential well site in the watershed must consider accidental highway spills from Route 3 and road salting.

Estimates of groundwater outflow show between 1.3 and 1.4 MGD of water is available to wells from this watershed. If induced infiltration is taken into account, as much as 2.4 to 2.9 MGD is estimated available. These estimates assume a well can be sited in the watershed.

TOWN OF HANSON

PRESENT CONDITIONS

In 1980, the Hanson water system served approximately 8,700 people. Over 99 percent of the town population is served by the Hanson Water Department. The average daily consumption was 0.6 million gallons per day (MGD). The average use per person served was about 78 gallons per day (MGD). The Water Department estimates that about 70 percent of the consumption is for domestic use, 10 percent for commercial, 15 percent industrial, and about 5 percent for undetermined and fire fighting use. A cranberry processing plant in Hanson utilizes about 21 million gallons of water during the period from September 15 through October 15. Agricultural water use not supplied by the Hanson Water Department is estimated at 0.45 MGD primarily from groundwater.

The town receives its water from the Brockton Water Commission which also supplies Brockton and Whitman. The primary source of water for the Brockton system is Silver Lake which is augmented by diversions from nearby areas. System safe yield is estimated at 13.4 MGD. Recently the town has developed an 18" diameter gravel-packed well and a 42" diameter well field that are expected to produce 350 and 400 gallons per minute, respectively. These sources will be brought into the system in October 1982 and will be used to meet the daily needs of the town with the Brockton system being called upon to meet peak demands. Information concerning sources and safe yields is presented in Table IV-9.

The Brockton Water Commission treats water in a 24 MGD capacity treatment plant that utilizes rapid sand filtration plus elemental additions.

About 99 percent of the current users are metered. Water is billed on a decreasing block structure with two blocks. Preventive maintenance, encouragement of the use of water saving devices, and a water conservation education program round out the conservation effort. The town is also planning to implement changes in the water rate structure.

Table IV-9

Brockton Water Commission
Water Supply Sources

Source	Safe Yield (million gallons per day)
Silver Lake	4.50
Monponsett Pond Diversion	5.40
Furnace Road Diversion	2.00
Avon Reservoir	1.50
	13.40

Newly Developed Sources Expected to be Utilized after October 1982

Well Type	Safe Yield (gallons per minute)
18" gravel-packed	350
42" well field	400

Safe yield from the newly developed sources estimated at 0.72 million gallons per day with pumps being run for 16 hours each day.

PROJECTIONS

Projections of future water demand are presented in Table IV-10.

Table IV-10

Projected Water Demand

Year	Average Daily Demand (MGD)	Maximum Daily Demand (MGD)
1990	0.8	1.6
2000	0.9	1.9
2010	1.1	2.1
2020	1.2	2.3

NEEDS

Hanson presently receives its water from the Brockton Water Commission which obtains water from a number of surface sources. Surface source safe yield must be able to meet the average daily demand imposed by the users. The Brockton system has been operating at close to its safe yield recently and reportedly has exceeded the safe yield during the summer months.

To compute water supply needs, it was assumed that the new wells would be brought into the system in October 1982 to provide 0.72 MGD and that the Brockton system could continue to supply Hanson with the 0.6 MGD that was consumed in 1980. It was assumed the Brockton system surface water sources will permit Hanson to meet maxiumum daily demands as in the past. Thus design demand and needs are based on average daily demand.

Table IV-11 summarizes the comparison of future demand and developed resources.

Table IV-11

Comparison of Demand and Supply

Year	Average Daily Demand (MGD)	Available from Brockton System and New Wells	Surplus (MGD)
1990	0.8	1.3	0.5
2000	0.9	1.3	0.4
2010	1.1	1.3	0.2
2020	1.2	1.3	0.1

GROUNDWATER RESOURCES

Portions of seven watersheds are located in the Hanson portion of the North and South Rivers Basin. Those located mostly within Hanson are Indian Head II, Indian Head III, and Little Cedar. Watersheds partially outside town boundaries are Indian Head I, Herring I, Herring III, and Drinkwater Brook. The remainder of the town which lies outside the North and South Rivers Basin was not included in this study.

Geologic maps show the Hanson watersheds to be underlain by large areas of sand and gravel. This stratified drift comprised over 50 percent of the land area in the watersheds. Saturated thickness of these sands and gravels is as much as 60 feet near the western shore of Oldham Pond, in the Herring III watershed. West of Indian Head Pond in the Indian Head watershed, saturated thickness of stratified drift approaches 40 feet. Other areas within the watersheds included in this study have been incompletely studied and are not used for groundwater supply. The western portions of Herring III and the northern portion of Indian Head II likely are underlain by an areally extensive surficial aquifer.

There is no groundwater pumpage from the Hanson portion of the watersheds.

Published reports indicate favorable areas for groundwater exploration within the seven Hanson watersheds. The potential is untested and based solely on interpretation of existing data.

The watersheds, Herring III, Indian Head II, and a small portion of Herring II are likely underlain by the regionally extensive aquifer identified by Goldberg-Zoino.

The transfer station off Franklin Street now handles Hanson's refuse. The old dump southwest of Indian Head Pond is abandoned.

There are at least five locations of underground flammable liquid storage in the watersheds. Some of these are located near ponds which are an expression of the water table (see Groundwater Hazards Map, Figure IV-4).

TOWN OF MARSHFIELD

PRESENT CONDITIONS

In 1978, the Marshfield water system served approximately 21,900 people during the winter months, increasing to about 35,000 in the summer. In addition, the town Water and Wastewater Division sells water to about 200 homes in the Duxbury Beach area of Duxbury. Water is also sold to the town of Scituate which distributes the water to 670 homes in the Humarock section. There are about 8000 services supplied by the Marshfield system. The homes in Duxbury Beach and Humarock represent about 11 percent of the total services. The average daily consumption was 2.8 million gallons per day (MGD). The average use per person served was about 96 gallons per day.

The town is supplied with water from a system of 12 wells. Information concerning well type, safe yield, and pumping capacity is presented in Table IV-12.

The two largest customers of the Marshfield Water Department are the town of Scituate and Marshfield Sand and Gravel Company. In 1978, Scituate bought about 83 million gallons and Marshfield Sand and Gravel used about 10 million gallons.

Table IV-12

Town of Marshfield
Water Supply Sources

Well	Well Type	Safe Yield and Pumping Capacity (gallons per minute
Ferry Street 1/	Gravel packed	525
School Street 2/	Gravel packed	400
Furnace Brook #1 2/	Gravel packed	750
Furnace Brook #2 2/	Gravel packed	350
Furnace Brook #3 2/	Gravel packed	600
Furnace Brook #4 2/	Gravel packed	1,000
Webster #1 2/	Gravel packed	350
Webster #2 2/	Tubular well field	350
Parsonage #1 3/	Tubular well field	250
Parsonage #2 3/	Tubular well field	300
Mt. Skirgo 4/	Tubular well field	400
South River 2/	Gravel packed	350

1/ Pumped 24 hours per day in summer and 4 hours per day in winter.

2/ In continuous rotation with wells sharing this footnote.

3/ Normally operated June-September.

4/ On line in winter months and used as needed; used more in summer.

Safe yield estimated by Marshfield Water Department as 4.5 MGD.
Safe yield of 0.1 MGD was assigned to service homes in Scituate.

PROJECTIONS

Projections of future water demand are presented in Table IV-13.

Table IV-13

Projected Water Demand

Year	Average Daily Demand (MGD)	Maximum Daily Demand (MGD)
1990	3.4	6.0
2000	3.9	6.8
2010	4.3	7.5
2020	4.7	8.3

NEEDS

Since Marshfield relies entirely on groundwater sources, the system safe yield must be able to meet the maximum daily demand. Table IV-14 summarizes the comparison of future demand and developed resources.

Table IV-14

Comparison of Demand and Supply

Year	Maximum Daily Demand (MGD)	Safe Yield (MGD)	Needs (MGD)
1990	6.0	4.4	1.6
2000	6.8	4.4	2.4
2010	7.5	4.4	3.1
2020	8.3	4.4	3.9

PREVIOUS STUDIES AND RECOMMENDATIONS

A report entitled "Marshfield Groundwater Resource Inventory" was prepared for the town in 1977-1978 by Goldberg Zoino Dunnicliff and Associates, Inc.

In the report the geohydrologic characteristics of several watersheds in Marshfield are described. Each was assessed on the basis of geology data gathered from available sources. The report is a preliminary document because of the accuracy limitations of the available data used.

Accompanying the report were maps showing aquifer recharge characteristics, potential yield and water quality hazards. The watershed map in this report is not meant to supersede the Goldberg maps.

Furnace Brook Watershed

The boundaries of the Furnace Brook watershed shown by Goldberg-Zoino are approximated as Furnace Brook on Figure IV-2.

Five municipal wells (Furnace Brook 1-4 and the School St. well) draw from this watershed. Total pumpage based on pumping of all wells at 16 hours a day is 2.9 MGD.

The northern and western part of the watershed is covered by an upper glacial till that rests in part on stratified sand and gravel deposits. Generally, the sand and gravel is thickest parallel to the valley axis. At higher elevations the upper till rests directly on denser impermeable lower till. South of School Street the Basin widens and the thickness of sand and gravel is somewhat greater.

Goldberg-Zoino state that logs of borings and previous published studies by USGS indicate a narrow elongated area along the axis of Furnace Brook possesses the highest yield in the Basin. The distribution of geologic divides and subsurface geologic relationships allowed them to perform a more detailed analysis of the hydrologic budget of the aquifer. They also estimated the potential for additional groundwater supply by a standard volumetric accounting method.

For the five month spring and summer budget period Goldberg-Zoino determined groundwater flow out of the Basin to be 689 million gallons. This allows for between 430 and 3700 million gallons remaining in storage.

Additional wells could capture this water in the lower portion of the Basin. Heavy withdrawals could affect the streamflow in Furnace Brook.

Management of any new well would need to consider effects of pumpage on the low flow of Furnace Brook. The Goldberg-Zoino report points out that groundwater mining may be judged to be acceptable as long as loss of streamflow is judged acceptable.

Littles Creek Watershed

This is a 900 acre watershed drained by Littles Creek.

The deposits of stratified drift consist of glacial outwash sand and gravel 30 to 90 feet thick. The sand and gravel is sandwiched between lower and upper tills.

Analysis of two pumping tests showed the aquifer to be a water table or unconfined system with high transmissivity, moderate storage, and of limited lateral extent.

Goldberg-Zoino determined that the southern half of the aquifer could sustain production of 600 gpm during a five month period. Characteristics of the aquifer showed that wells should be widely separated to avoid pumping interference. This would allow maximization of the capacity of an otherwise areally limited aquifer. The thickest and potentially most productive area of this watershed is a strip of stratified drift deposits about 6000 feet long.

Recommendations for further explorations in the southern half of the aquifer on the boundary with the Fairgrounds watershed were made in the report.

The northern half of the aquifer was also recommmended for further study. Small areas of sand and gravel are surrounded by large areas of glacial till which contribute to the stratified drift. The authors rated this northern area as having lower potential than the southern half of the aquifer.

Fairgrounds Basin Watershed

This is an area of about 1300 acres located in a depression between Carolina and Telegraph Hills. Drainage is poorly defined in the northern part of the Basin. Three small streams drain the southern portion of the aquifer.

Deposits underlying the Fairgrounds watershed likely represent ice contact stratified drift.

Stratified deposits north of the escarpment are mostly outwash deposits. There is extensive sand and gravel mining east of the railroad where sands about 50 feet thick exist above the water table.

The maximum thickness of stratified deposits occurs in a zone of high potential yield about 1500 feet wide. The School Street Well is located within this area. Analysis of a pump test north of the Fairgrounds in the high potential yield zone indicated moderate transmissivity and high permeability. Goldberg-Zoino concluded that water extracted from the aquifer was taken from storage and was not induced surface water.

Recommendations on areas for further groundwater investigation were made by Goldberg-Zoino.

SOUTHERN MARSHFIELD WATERSHEDS

Green Harbor River, Halls Pond, and Webster House watersheds are located in southern Marshfield.

Green Harbor River Watershed

This is a large watershed draining 1300 acres in Duxbury and about 1380 acres in Marshfield. Goldberg-Zoino indicates that half of the watershed consists of river-edge marsh below Garretson Pond.

Outwash deposits bound the northern part of the aquifer. The central portion consists mostly of kame deposits and other glacio-fluivial deposits.

A 12-day, 204 gpm pump test performed in April 1973, indicated the aquifer to be a water table type with relatively high transmissibility. Results showed water was being pumped from storage within the aquifer and did not induce recharge from a surface water source.

Goldberg-Zoino did not prepare a water budget analysis of the aquifer due to insufficient data. Areas of major groundwater potential within southern Marshfield cover about 45 acres. Recommendations were made to explore one potential area on the west side of Black Mountain and a second near the golf course off Webster Street.

Hall's Pond Watershed

This watershed covers about 475 acres. Hall's Pond acts as a discharge area for groundwater moving from areas of higher elevation west, north, and east of the pond. On the south, Hall's Pond watershed is bounded by Duxbury Marsh.

Stratified glacial deposits cover all the watershed above elevation ten feet. West of Hall's Pond are stratified kame deposits of fine to medium sand with gravel beds. Coarse grained sand and gravel ice contact deposits border the north and east side of Hall's Pond. At test site 4-73 a prolonged pumping test showed that these deposits form a water table aquifer with moderate transmissivity and high permeability.

Two prolonged aquifer tests were conducted at site 4-73 off Webster Street. The first determined the site possessed moderate production capacity and the second 29-day test indicated iron and manganese content of the water would not be a deterrent to groundwater development. Goldberg-Zoino concluded that transmissibiity of the aquifer probably ranges from 20,000 to 50,000 gpd/ft. This test suggested that there is a hydraulic connection between the aquifer and a small pond to the north, creating induced infiltration. In addition, the pumping cone of influence intercepted an area of lower transmissivity east of the site. Projection of the long-term effects of those characteristics suggests significant declines in saturated thickness and possible excessive drawdowns would result.

In 1979, another pump test was conducted in the Hall's Pond aquifer about 650 feet southeast of well 4-73. In this area the aquifer is artesian. Analysis of test data suggests a possibility of induced salt water under long-term pumping.

Recommendations were made to investigate a site between Hall's Pond and the pumped well at 139-78.

Webster House Watershed

This small watershed lies east of the salt water intrusion line drawn by Goldberg-Zoino. No test wells drilled in the watershed were deemed to be significant for municipal supply. If developed, salt water would likely be pumped to the wells.

TOWN OF NORWELL

PRESENT CONDITIONS

In 1982, the Norwell water system served approximately 9600 people. The average daily consumption was 1.1 million gallons per day (MGD), a per capita demand of 115 gallons per day. Domestic use is estimated to account for 70 percent of use, commercial use for 15 percent, industrial for 10 percent, and agricultural for 5 percent.

The town is supplied with water from a system of nine wells Information concerning safe yield and pumping capacity is presented in Table IV-15.

No treatment of the water supply is currently employed. The primary water quality problem is sodium. Levels exceeded the recommended maximum level (20 mg/l) during 1979.

About 95 percent of the users are now metered. Other conservation efforts have been limited to the banning of nonessential uses when necessary.

Table IV-15

Town of Norwell
Water Supply Sources

Well	Safe Yield and Pump Capacity (gallons per minute)
#1 1/	350
#2 1/	240
#3 1/	180
#4 1/	315
#5 1/	300
#6 1/	350
#7 2/	200
#8 2/	145
#9	120

1/ Operated 12 hours per day in three 4-hour periods.

2/ Operated 6 hours per day in three 2-hour periods.

System safe yield estimated at 2.1 million gallons per day with all pumps being run at safe yield for 16 hours each day. System yield under the operating plan described in Table IV-15 footnotes is estimated at 1.7 MGD.

PROJECTIONS

Projections of future water demand are presented in Table IV-16.

Table IV-16

Projected Water Demand

Year	Average Daily Demand (MGD)	Maximum Daily Demand (MGD)
1990	1.4	2.4
2000	1.6	2.7
2010	1.8	3.0
2020	1.9	3.3

NEEDS

Since Norwell relies entirely on groundwater sources, the system safe yield must be able to meet the maximum daily demand. Table IV-17 summarizes the comparison of future demand and developed resources.

Table IV-17

Comparison of Demand and Supply

Year	Maximum Daily Demand (MGD)	Safe Yield 1/ (MGD)	Needs (MGD)
1990	2.4	2.1	0.3
2000	2.7	2.1	0.6
2010	3.0	2.1	0.9
2020	3.3	2.1	1.2

1/ Safe yield based on pumping all wells 16 hours per day. Yield is 1.7 MGD if wells are pumped at present operating sequence.

PREVIOUS STUDIES AND RECOMMENDATIONS

Whitman and Howard, Consulting Engineers, in 1980 made the following recommendations concerning groundwater:

1. Test well exploration should be initiated after geologically favorable areas are identified.

2. Gravel packed wells and accompanying pumping stations and equipment should be constructed at favorable sites.

GROUNDWATER RESOURCES

Three watersheds, Stony Brook, Second Herring, and Wildcat Brook are totally within the Norwell boundaries. Portions of three other watersheds, Lower Third Herring, Upper Third Herring, and Longwater-Shinglemill, are mostly within the town. Upper First Herring and Lower First Herring are discussed in the Scituate section. Longwater-Shinglemill is discussed in the Hanover section of this report.

Stony Brook Watershed

This 516 acre watershed is located in the eastern portion of Norwell. Stony Brook and a small unnamed tributary drain the area. Stony Brook flows on glacial till from Cross Street to where it meets the salt marshes near King's Landing.

Approximately 15 percent of the watershed is stratified drift, the remainder being glacial till and swamp deposits. USGS (Williams and Tasker, 1974) show saturated thickness of stratified drift to approach 80 feet in places. A deep preglacial valley appears to extend southeast-northwest from the Lower Herring Brook aquifer and into the Stony Brook aquifer. Well logs show favorable soil types for well development.

Groundwater and surface water divides are likely coincident in glacial till soils in the west and northwest sections of the aquifer. Where stratified sand and gravel is exposed in the Satsuit Meadow area, seasonal differences may result in shifting of the groundwater divide.

No municipal pumpage is taken from this aquifer. The closest municipal wells are located east of a probable groundwater divide in Scituate.

There are no known locations of underground flammable liquid storage or landfills in the watershed.

Second Herring Watershed

This watershed is a 2340 acre area which extends north-south from near Clapp's Corner at the Scituate-Norwell boundary to south of Norwell Center. Black Pond Swamp and Dead Swamp are the two major wetlands within the boundaries. Norwell Center is located in the southern part of the watershed.

The surficial geology of this watershed is dominated by glacial till. Three areas of stratified drift are shown by USGS (Williams and Tasker, 1974). Saturated thickness of the northern two of these areas is estimated to be less than 20 feet. The greatest thickness of saturated stratified drift as shown by USGS is located in the discharge area of the watershed near the North River. Well data indicate soils to be glacial till overlying stratified sands and gravels in this third area.

At present there are no municipal wells pumping from this watershed.

A review of salt storage sheds, dumps, landfills, and underground flammable liquid storage showed only one potential pollution source.

In the Second Herring Watershed, potential additional supply is limited to a restricted area. This is the geologically favorable area in the watershed. Table IV-1 shows the groundwater estimated available to properly sited wells.

TOWN OF PEMBROKE

PRESENT CONDITIONS

In 1979, the Pembroke water system served approximately 13,500 people. Over 99 percent of the town population is served by the Pembroke Water Department. Small areas of town are served by the Abington-Rockland Water Works, Brockton Water Department, and Marshfield Water Department. The average daily consumption was 0.8 million gallons per day (MGD). The average use per person served was 62 gallons per day. There are no significant industrial, commercial, or agricultural users on the system. Irrigation and flooding of cranberry bogs represent the most significant consumption of water not provided by the Pembroke Water Department. The water is obtained from surface sources.

The town is supplied with water from a system of three wells. System safe yield is estimated at 1.8 MGD. Information concerning well safe yield and pumping capacity is presented in Table IV-18.

Table IV-18

Town of Pembroke
Water Supply Sources

Well	Safe Yield Gallons/Day
#1 1/	500,000
#2 2/	900,000
#3 1/	500,000

1/ Well #1 operates in constant rotation with Well #3.

2/ Well #2 is used June through October in order to supplement the supply obtained from wells 1 and 3.

System safe yield is estimated at 1.8 million gallons per day based on testing.

The water is treated with soda ash to counter a low pH problem. Iron is also a water quality problem. Fluoride is added to the water to promote dental health.

All of the present users are metered. Water is billed to users on a decreasing block rate. No other active water conservation efforts are underway.

PROJECTIONS

Projections of future water demand are presented in Table IV-19.

Table IV-19

Projected Water Demand

Year	Average Daily Demand (MGD)	Maximum Daily Demand (MGD)
1990	1.1	2.4
2000	1.3	2.8
2010	1.4	3.1
2020	1.6	3.5

NEEDS

Since Pembroke relies entirely on groundwater sources, the system must be able to meet the maximum daily demand. Table IV-20 summarizes the comparison of future demand and developed resources.

Table IV-20

Comparison of Demand and Supply

Year	Maximum Daily Demand (MGD)	Safe Yield (MGD)	Needs (MGD)
1990	2.4	1.8	0.6
2000	2.8	1.8	1.0
2010	3.1	1.8	1.3
2020	3.5	1.8	1.7

PREVIOUS STUDIES AND RECOMMENDATIONS

Pembroke groundwater resources have been covered in two previous reports. USGS Hydrologic Atlas MA-504 includes Pembroke, as does a 1977 Old Colony Planning Council Report entitled "Groundwater Resources in the Old Colony Planning Council 208 Area." The latter report includes a general discussion of groundwater supplies as it pertains to the two towns within the North and South Rivers Basin, Pembroke, and Hanson. A series of six maps, including a surficial materials map, exploration map, groundwater contour amp, saturated thickness map, confined aquifer map, and transmissivity map provide an up-to-date, townwide study of geologic data for Pembroke. Geological explorations were also performed as part of the study.

The Old Colony Planning Council Report included some seismic refraction profiling. Those findings were incorporated into the groundwater resource maps. Recommendations for further study were not given.

GROUNDWATER RESOURCES

Portions of eight watersheds are located in Pembroke. Those which are almost totally in the town are Pudding I, Robinson, Herring I and Herring II. Those watersheds partly outside of the town boundaries are Pudding II, Magoun, Keene Brook, and Indian Head.

A broad area bordering Swamp and Herring Brooks was not included in the analysis. This lowland area is under tidal influence. USGS shows this area to be subject to potential salt water intrusion (Williams and Tasker, 1974).

Geology maps of Pembroke indicate large expanses of stratified, highly transmissive sands and gravels. These sands and gravels make up regionally extensive aquifers with low groundwater gradients. This situation results in groundwatersheds which do not correspond to surface watersheds. The surface watersheds shown on the map reflect local groundwater flow patterns. The deeper regionally extensive gravels and sands, however, follow regional flow patterns often irrespective of surface topography. Geology of the town will be discussed here rather than the individual watersheds. Goldberg-Zoino, in their report to the Old Colony Planning Council indicate an extensive aquifer system, where groundwater divides and surface water divides do not necessarily coincide and underflow would likely take place between watersheds. Watersheds are listed on Table IV-1 with the groundwater outflows. These outflows are shown for estimate purposes only.

The OCPC Report indicates that a thickness of over 80 feet of saturated sands and gravels exists in areas of this southwestern area of Pembroke. This aquifer with its associated surface expression of lakes, supplies water to a large part of the area's population and underlies the watersheds of Herring I, Herring II, a portion of Herring III, and Indian Head. Saturated thicknesses are greatest in the area about 2500 feet east of Little Sandy Bottom Pond. Groundwater elevations indicate flat gradients in the area. In general, watersheds of Pembroke southwest of Swamp Brook are highest in percent of stratified sand and gravel. Values in Table IV-1 for the maximum water available for these watersheds may underestimate the total water available due to regional groundwater flow between watersheds.

There is considerable pumpage from this portion of the Basin. The Brockton Water System takes 13.4 million gallons per day from Silver Lake and associated pond diversions. Pembroke pumps 1.5 MGD from three wells in the area. Great Sandy Bottom Pond also acts as a water supply for Abington and Rockland.

The area of Pembroke underlain by the regional aquifer system is the most highly productive groundwater area in the North and South River Basin study area.

Future groundwater potential is greatest in this five watershed area. Future explorations should be directed in this area. A well has been located about 600 feet east of Little Sandy Bottom Pond. Water Department officials indicate the well to have good potential.

Watersheds Herring I, Herring II, Herring III, and a portion of Indian Head overlie the southwest aquifer system. There is likely to be substantial underflow between watersheds. Groundwater gradients are nearly flat, differing by only ten or twenty feet. Contamination in any one of the watersheds is a potential hazard to all downgradient groundwater. Regional flow patterns could make it possible for contaminants to travel throughout large areas of this aquifer.

There are at least eight locations of underground flammable liquid storage in the five watersheds. Some of these are located near ponds which are an expression of the water table.

A sanitary landfill in Pembroke poses a potential hazard to ground and/or surface water supplies. Many miles of highway crisscross the area. The permeable soils are vulnerable to road spills and salting.

TOWN OF ROCKLAND

PRESENT CONDITIONS

Rockland is supplied water by the Abington-Rockland Joint Water Works. For purposes of this analysis, no attempt was made to disaggregate demand or supply to individual towns; figures presented in tables reflect the entire Abington-Rockland system.

In 1980, the system served approximately 29,200 people. Over 99 percent of the town population is served by the water system. The Abington-Rockland system also supplies residents in Pembroke, Hanson, Hingham, and Norwell with water as they lie on the fringe of their local systems. The average daily consumption was 2.5 million gallons per day (MGD). The average use per person served was about 86 gallons per day. About 86 percent of the water is for domestic use, 5 percent for commercial, 8 percent for industrial, and 1 percent for agricultural use.

The system is supplied with water from two wells and two surface reservoirs. System safe yield is estimated at 2.4 MGD. Information concerning well safe yield, pumping capacity, reservoir safe yield and treatment plant capacity is presented in Table IV-21.

Table IV-21

Abington-Rockland Joint Water Works
Water Supply Sources

Well	Pump Capacity (gallons per minute)
#1 - Sandy Bottom	200
#1 - Meyers Ave.	700
#2 - Meyers Ave.	48

In addition to the wells, the system utilizes two surface sources.

Reservoir	Safe Yield
Great Sandy Bottom Pond	0.75
Hingham Street Reservoir	0.60
	1.35

Surface water is conventionally treated at the Hingham Street Water Treatment Plant. The Great Sandy Bottom Plant utilizes screen filtration and chlorination along with the addition of well water. Groundwater is treated with alum, caustic, potassium permanganate, chlorine, sodium metaphosphate. Pressure filtration is also used.

Two wells at Great Sandy Bottom Pond have been abandoned due to iron, manganese, and color problems. Additional wells at Fox's Pit in Rockland were abandoned as the system filtration plant could not remove organic constituents. Water quality at Great Sandy Bottom Pond is a continuing concern to the operators of the water system. Treatment facilities could alleviate that concern.

All of the users are metered. Water is billed at a constant rate per 100 cubic feet. Heat detection studies are used to locate leaks. The system has a meter, valve, and hydrant maintenance program. Flow reduction devices have been distributed through the local gas company. Nonessential uses are banned when conditions dictate. A water conservation education program is used in the schools and pamphlets on conservation are distributed to customers.

The Great Sandy Bottom filtration plant has a capacity for 1.5 MGD without using a booster pump and 2.2 MGD with the booster pump. The Hingham Street Treatment Plant is designed for 2 MGD but has a hydraulic capacity for 3 MGD.

PROJECTIONS

Projections of future water demand are presented in Table IV-22.

Table IV-22
Projected Water Demand

Year	Average Daily Demand (MGD)	Maximum Daily Demand (MGD)
1990	2.9	5.2
2000	3.3	5.9
2010	3.8	6.8
2020	4.3	7.7

NEEDS

Since the Abington-Rockland system relies on a combination of groundwater and surface water sources, it was assumed that the system must meet a demand halfway between the average and maximum daily demand. Table IV-23 summarizes the comparison of future demand and developed resources.

Table IV-23
Comparison of Demand and Supply

Year	Design Demand (MGD)	Safe Yield (MGD)	Needs (MGD)
1990	4.1	2.4	1.7
2000	4.6	2.4	2.2
2010	5.3	2.4	2.9
2020	6.0	2.4	3.6

PREVIOUS STUDIES AND RECOMMENDATIONS

In 1953, the Abington-Rockland Joint Water Board contracted with Weston & Sampson, Consulting Engineers, for an exploration program to locate potential groundwater sources. Eighty-six test wells were drilled (primarily in Rockland, with some in Abington and Pembroke). Results were disappointing with only one well in the Fox gravel pit near Market Street being recommended for development. Wells were eventually drilled at the site but later abandoned due to a color problem which could not be removed by the filtration plant.

The Joint Water Works has identified three alternative sources of water supply to meet future needs:

1. Expansion of the Hingham Street Reservoir;
2. Development of another well in the Meyers Avenue area;
3. Development of groundwater sources in the vicinity of the Great Sandy Bottom Pond pumping station.

GROUNDWATER RESOURCES

Portions of five watersheds are located within town boundaries. These are Upper and Lower French Stream, Cushing Brook, Mann Brook, and Shinglemill. Of these, Shinglemill extends into Hanover and Upper French Stream extends into Abington and Weymouth.

Mann Brook Watershed

This 1.68 square mile watershed originates in Hingham east of Accord Pond and drains an elongated area of about 0.75 mile wide by nearly 2.5 miles long. Mann Brook leaves Rockland and crosses into Hanover about halfway through its course and joins Cushing Brook in the western part of Hanover.

Surficial geology is composed of about 40 percent stratified drift, with the remainder being till and swamp deposits. Several borings drilled in the Rockland portion of the watershed indicate very difficult drilling with up to 20 feet of sand and gravel overlying glacial till.

No wells pump from this watershed at present. The Hingham Street Reservoir is located in the watershed.

There are two locations of underground flammable liquid storage in the watershed. Road salting and accidental highway spills pose additional potential hazards to the Hingham Street reservoir or any future groundwater developments.

Table IV-1 estimates that a maximum of between 1.34 and 1.42 MGD supply is available to a well. This maximum amount includes induced infiltration.

Cushing Brook Watershed

The Cushing Brook watershed is nearly three square miles in area extending about 3.5 miles by about 1 mile. The brook originates and drains the eastern portion of Rockland. The brook flows through several swamps, finally emptying into the Drinkwater River and Forge Pond. The southeastern portion of the watershed extends into Hanover.

USGS indicates the watershed is underlain by about 54 percent stratified drift. Two large, primarily peat swamps, make up a significant part of the watershed. Many borings have been made in this watershed, mostly between Market Street and Webster Street. The 1953 Weston and Sampson study sited a well at Fox's Pit which yielded about .6 MGD until abandoned due to high color problems. This well was located in the most promising area for groundwater in the watershed. Borings in the Fox's Pit area indicate refusal depths that average about 20 feet. A favorable groundwater area is shown by USGS in the Fox's Pit area.

Although no wells are presently pumping from the watershed, pumpage has taken place in the past, and potential for siting a well in this watershed exists.

There are appoximately 20 locations of underground flammable liquid storage within the watershed boundaries. A new landfill, located off Pleasant Street, is shown on the potential hazards map, Figure IV-4.

Table IV-1 indicates that between 1.45 and 1.65 MGD is available for pumpage. If induced infiltration is included from Cushing Brook approximately another 1.23 MGD could be pumped. The total water available for pumpage, then, is estimated between 2.7 and 2.8 MGD. This watershed is rated as moderate potential for additional groundwater supply.

Upper French Stream Watershed

The Upper French Stream watershed extends from the South Weymouth Naval Air Station in Weymouth, including a large portion of western Rockland and a portion of Abington. French Stream rises in the airport area. Drainage near the Air Station has been changed by the military installation. USGS shows the stream nearly divides the stratified drift on the west from the till on the east. The watershed is about 1.5 miles wide by 2 miles in length. The French Stream drainage continues southward where it empties into Studley Pond.

Topographic divides and groundwater divides probably coincide on the eastern side of the watershed where till makes up the boundary between the aquifer and the Old Swamp River watershed. Groundwater divides along the northern and western boundaries are subject to seasonal variations. Underflow from this watershed could be expected in these areas into adjacent drainage areas.

USGS surficial maps show about 46 percent of the watershed is covered with stratified drift along a linear belt on the western edge of the watershed. A large expanse of glacial till covers the eastern portion of the watershed. Borings drilled for Weston and Sampson in 1953 showed shallow refusal in many borings near Studley Pond.

No water is pumped from this watershed at present.

Table IV-1 shows an estimate of the total amount of water available over a long time period, The long-term maximum available from groundwater supplies only is estimated to be 2.81 MGD. Estimated maximum water available including induced recharge ranges from 4.0 MGD to 4.1 MGD.

Within the Rockland portion of the watershed USGS shows less potential for high capacity wells to be developed. Where the watershed extends into Abington and Weymouth, greater potential exists for municipal supply.

Within the Rockland portion of the watershed there are three sections of underground gasoline storage. In addition, two sewage treatment plants operate in the watershed. The Naval Air Station in Weymouth with large areas of runways could also present potential hazards to a newly developed well field. Potential hazards in Abington and Weymouth were not inventoried for this report.

Lower French Stream Aquifer

This watershed covers a 4.7 square mile area south of Rockland. Beech Hill Swamp dominates the southern portion of the watershed. The watershed is approximately 3 miles long by 2 miles wide. French Stream flows to Hanover where it empties into Forge Pond.

USGS surficial maps indicate about 42 percent of the Basin is composed of stratified drift. The remainder is covered by low permeability swamp and glacial till. The Beech Hill Swamp surface is shown as peat, consisting of partially decomposed plant remains on the soils map. The USGS report by Williams and Tasker shows maximum saturated thickness of stratified drift to be 40 feet near Esten School. Generally, thickness of saturated stratified drift is 20 feet or less throughout the watershed. Test wells 1-4 between Summer Street and West Hanover indicated at least 68 feet of unconsolidated material. USGS indicates a geologically favorable area for groundwater south of these four wells.

Generally, it appears groundwater divides and surface water divides coincide at the western boundary of the watershed along till slopes. In the remainder of the watershed where not bounded by till, divides may not coincide.

Currently, no municipal water supply is taken from this watershed.

This watershed is characterized by large areas of glacial till and relatively shallow areas of stratified sands and gravels. Table IV-1 indicates that between 2.11 and 2.33 MGD could be pumped from the aquifer where wells would not be in direct hydraulic connection with the brook. Including the 90 percent duration flow of the French Stream, an additional 1.81 MGD available, considering drying the brook for 10 percent of the time. This watershed is rated as moderate potential for future supply.

Near the potential groundwater source on Summer Street there are two gasoline storage locations. About 3000 feet northeast of this area are three additional gasoline storage locations and a salt storage area.

TOWN OF SCITUATE

PRESENT CONDITIONS

In 1979, the Scituate water system served approximately 17,800 people during the winter months increasing to about 30,000 in the summer. Nearly all of the town population is served by the water department. The average daily consumption was 1.6 million gallons per day (MGD). The average use per person served was 92 gallons per day based on a year-round equivalent population of 21,000. Domestic use accounts for about 70 percent of consumption, commercial use for 15 percent, industrial for 10 percent, and agricultural use for 5 percent.

The town is supplied with water from a system of six wells and a surface reservoir. At least six other wells have been permanently or temporarily abandoned due to water quality or yield problems. Information concerning the wells, safe yield, and the reservoir is presented in Table IV-24.

Table IV-24

Town of Scituate
Water Supply Sources

Well	Safe Yield (gallons/minute)
10 - Webster's Meadow	142
11 - Webster's Meadow	77
17 - Stearns Meadow	253
18 - Boston Sand & Gravel	139
19 - Edison	292
22 - Barnes Meadow	269
1 - Spring Street	1/
2 - Kent Street	140 2/
3 - Beaver Dam	110 3/
9 - Webster's Meadow	210 3/
12 - Bound Brook	140 3/
20 - Jenkin's Place	160 4/

1/ Abandoned well - believed to have been part of Beaver Dam well field.

2/ Temporarily abandoned due to high manganese and hardness levels.

3/ Abandoned - replaced by more efficient well.

4/ Discontinued use due to high iron and manganese levels.

In addition to the wells, the town utilizes First Herring Brook Reservoir and Old Oaken Bucket Pond which have a safe yield of 0.75 MGD. The reservoir system is utilized during summer months to supplement groundwater sources.

Surface water is treated at the 2.75 MGD capacity Old Oaken Bucket Pond Water Treatment plant using chemicals and filtration. Groundwater does not require treatment.

System safe yield is estimated at 2.4 MGD.

About 95 percent of the present water users are metered. Water is billed at $0.50 per 100 cubic feet. Leak detection studies and preventative maintenance are used in the water conservation program. Changes in the rate structure, encouragement of water-saving devices, and protection of groundwater sources are being considered.

PROJECTIONS

Projections of future water demand are presented in Table IV-25.

Table IV-25

Projected Water Demand

Year	Average Daily Demand (MGD)	Maximum Daily Demand (MGD)
1990	1.7	3.4
2000	1.9	3.8
2010	2.1	4.2
2020	2.3	4.6

NEEDS

Scituate obtains its water supply from a combination of surface and groundwater sources. Ordinarily, this combination of resources would indicate that the town need only meet average daily demand with system safe yield. However, since the surface water supply requires treatment, system safe yield must be adequate to meet maximum day demand. Table IV-26 summarizes the comparison of future demand and developed resources.

Table IV-26

Comparison of Demand and Supply

Year	Maximum Daily Demand (MGD)	Yield (MGD)	Needs (MGD)
1990	3.4	2.4	1.0
2000	3.8	2.4	1.4
2010	4.2	2.4	1.8
2020	4.6	2.4	2.2

Based on projected constant population. See Table I-5 for population data and projections.

PREVIOUS STUDIES AND RECOMMENDATIONS

In 1975, town officials completed a study of water resources and future needs. Although there are some differences in population and safe yield estimates between the 1975 report and this study, the conclusion of both reports is the same; additional water supply sources must be developed to meet projected demands.

The 1975 report suggested several alternatives to meet needs:

1. Development of a new well - The town water resources committee recognized that development of a new well would be the most economical way to meet needs. However, due to the number of wells that had been abandoned in the past, Weston Geophysical Engineers, Inc. were retained to study available data, conduct seismic surveys, and recommend areas that warrant further exploration for a municipal well. Three areas were suggested for further study:

   a. East of Brushy Hill between Stockbridge and First Parish Road,

   b. Satsuit Meadow adjacent to the Norwell town line, and

   c. The South Swamp-Cedar Street-Clapp Road area in the northwest corner of town.

*2. Recharge of the Boston Sand and Gravel (Well Number 18) aquifer by pumping water that is currently spilled from Old Oaken Bucket Pond.

*3. Utilize the abandoned Well #21 in Wagners Meadow by pumping through the water treatment plant. Well #21 was abandoned in 1968 due to high iron and manganese levels.

4. Construction of a reservoir on First Herring Brook in the vicinity of Grove Street and Pincin Hill near the Norwell town line. A preliminary study of the site by Whitman & Howard, Consulting Engineers, indicated that the site might provide up to 0.66 MGD of safe yield.

*5. Restoration of the Kent Street and Beaver Dam well fields.

*The town presently feels that these recommendations are not viable alternates.

GROUNDWATER RESOURCES

Lower First Herring Watershed

The Lower First Herring Aquifer is a 1.4 square mile watershed dominated by two large marshy areas. The first, Satsuit Meadow drains through cranberry bogs to Tack Factory Pond. A second marshy area southeast of Brushy Hill drains to Old Oaken Bucket Pond, which empties to salt marshes at the North River. The watershed extends one-half mile north to south and about two miles east to west. The watershed is divided by Route 3A.

Surficial geologic maps show about 79 percent of the aquifer is covered by low permeability glacial till and swamp deposits. The remaining surface area consists of permeable stratified sands, gravels, and alluvium. Topographic and groundwater divides appear to be coincident in areas of till deposits near Walnut Tree and Buttonwood Hills. In areas of low topography between the two hills or west of Satsuit Meadow groundwater divides may not be reflective of surface water divides. Williams and Tasker (1974), show the greatest saturated thickness of stratified drift to be southwest of Walnut Tree Hill. Weston Geophysical (1977), also show up to 40 feet of favorable soils in this Satsuit Meadow area.

The Fitts Well, #20, is used only during drought periods. If pumped for 16 hours, 153,600 gallons could be obtained.

Within the Lower First Herring Aquifer an old dump is located north of Stockbridge Road. Improper past management may cause adverse impacts on water quality of the Fitts Well, due to leachate contamination. The old dump is located on a marshy area within 1500 feet of the Fitts Well. In addition, four locations of underground flammable liquid storage were found in the watershed. The location of these storage sites is downgradient of any pumping wells. An accidental spill would likely not contaminate water supplies.

Upper First Herring Watershed

The Upper First Herring Watershed occupies the headwaters and upper reaches of First Herring Brook. The brook rises in South Swamp and flows in a southeasterly direction around the base of Pincin and Doctor's Hills. The total drainage area is four square miles. Dimensions of the watershed are approximately 1.5 miles north-south by 2.5 miles east-west. The brook empties into Tack Factory Pond just east of Route 3A.

Surficial geologic maps show 90 percent of the Basin is covered by glacial till deposits. The remainder of the watershed is comprised mostly of stratified sands, gravels, and alluvium. USGS (Williams and Tasker, 1974) shows glacial till overlying sands and gravels along the axis of First Herring Brook. The axis of the brook generally reflects a deep glacially scoured valley which has been subsequently filled with glacially derived sands and gravels. Topographic and groundwater divides appear to coincide throughout the Basin due to till mantled hills. Saturated thickness of the deposits is shown to be as much as 90 feet in places. This watershed is one of the most productive groundwater areas in Scituate.

Present pumpage from the Upper First Herring Brook Aquifer comes from three wells: Edison #19, Barnes Meadow #22, and Sterns Meadow #11. Locations of the wells are shown on Figure IV-3.

Table IV-1 shows estimated groundwater contribution to the wells from recharge to the surface watershed.

Within the Upper First Herring Watershed there are several potential pollution sources. A town salt shed is located near the small intermittent tributary to First Herring Brook. All three wells pumping from the aquifer are situated downgradient from the salt shed. A second potential hazard is Route 3A, which passes less than 300 feet from Well #19. Highway salting could have a negative impact on water quality. Three locations of underground storage of flammable liquids within the watershed are located downgradient of present wells. These storage areas, however, are located directly uphill of the Scituate surface water supply reservoir.

The watershed has been extensively explored for water. Sufficient thicknesses of stratified sands and gravels exist to warrant inclusion of this area in a townwide groundwater evaluation.

Webster's Meadow Wells #10, #11

The contributing surface watershed for these wlls is located outside the two previously mentioned watersheds.

The two wells are located in one of the thickest areas of stratified drift in the River Basin. USGS shows a saturated thickness of up to 120 feet of stratified drift in the glacially scoured pre-glacial valley.

At present, Wells #10 and #11 are pumped at 140 gpm and 77 gpm, respectively.

Within the well watersheds there is one location of underground flammable liquid storage. Other potential hazards could be salting of Route 123 and accidental highway spills.

The area near these two wells has a high potential for groundwater development. Wells #10 and #11, pumping since the 1930's, may not be fully tapping the aquifer's potential.

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