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EPA

Capsule Report

Lake Restoration in Cobbossee Watershed

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Lake Restoration in Cobbossee Watershed

July 1980

*This report was developed by the
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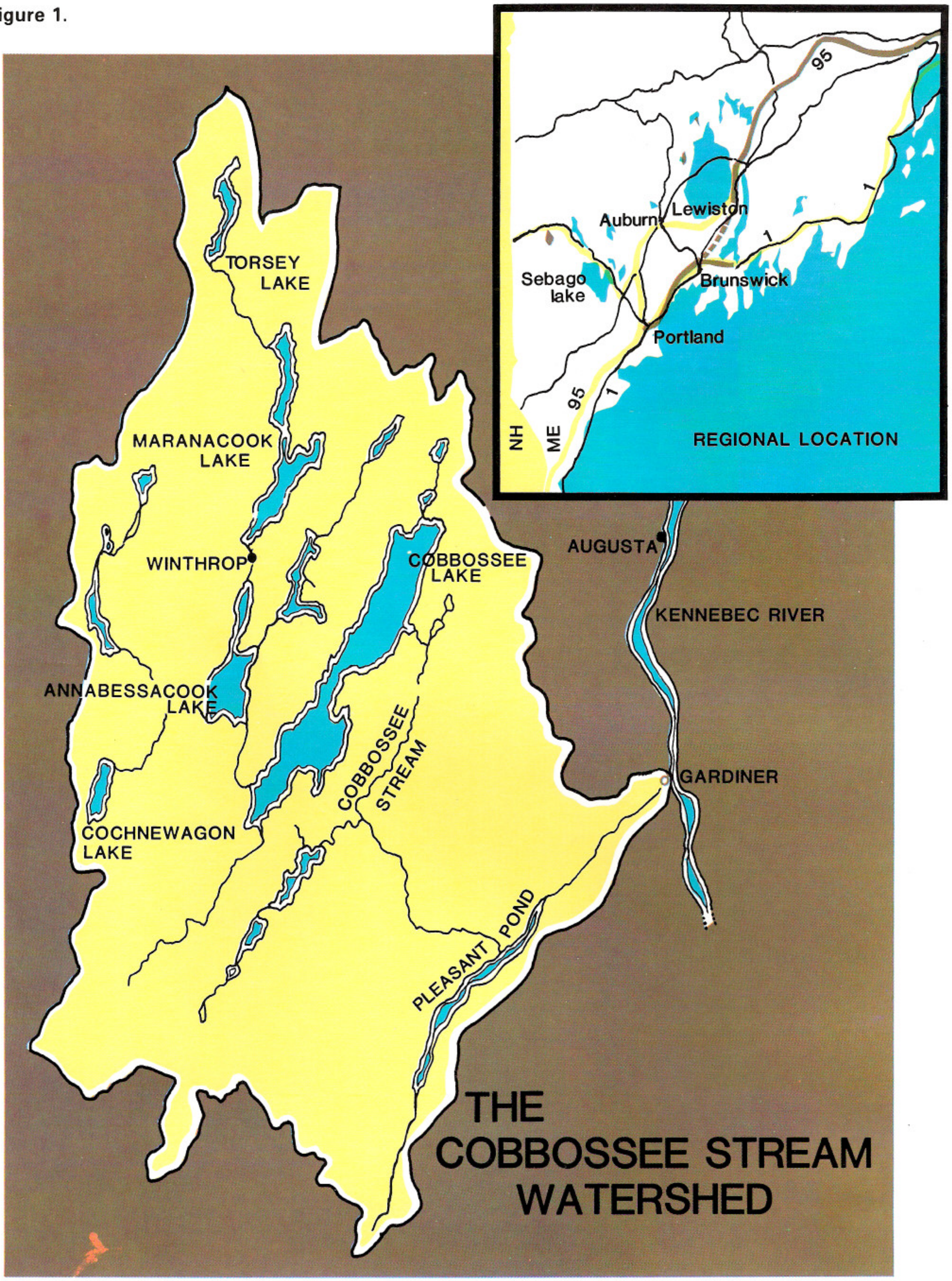
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268*

Figure 1.


TORSEY LAKE
MARANACOOK LAKE
WINTHROP
ANNABESSACOOK LAKE
COCHNEWAGON LAKE
COBBOSSEE LAKE
COBBOSSEE STREAM
PLEASANT POND
AUGUSTA
KENNEBEC RIVER
GARDINER
THE COBBOSSEE STREAM WATERSHED
Lewiston
Auburn
Sebago lake
Brunswick
Portland
95
1
NH
ME
REGIONAL LOCATION

I. Introduction

The Clean Lakes program was initiated in 1975 to implement section 314 of the Federal Water Pollution Control Act Amendments of 1972. Section 314 gives the States the responsibility for protecting and restoring the quality of freshwater lakes. The program provides funding to assist the States in classifying their lakes according to water quality, identifying methods to control pollution sources affecting them, and restoring those which have been degraded. To qualify for a Clean Lakes restoration grant, a lake must be open and accessible to the public. Furthermore, the proposed restoration project must have the potential to yield long-term public benefits and not merely temporary or superficial improvement.

This report discusses lake restoration in the watershed of Cobbossee Stream, which drains 562 square kilometers (217 square miles) of Kennebec County immediately west of Augusta, Maine (Figure 1). The Cobbossee Watershed contains 28 lakes, three of which — Annabessacook Lake, Cobbossee Lake, and Pleasant Pond — are classified as eutrophic (see Table 1). Lake restoration efforts had been underway since the 1960's, but despite substantial progress, including eliminating industrial and municipal discharges, nuisance conditions in the three lakes persisted. It became obvious that partial solutions to the watershed's pollution problems were not going to be sufficient to restore lake water quality. Clean Lakes funds made it possible to develop and carry out a comprehensive restoration program which included alum treatment of one of the lakes and implementation of agricultural pollution control practices in the direct drainage areas of all three.

Table 1.

Lake and Watershed Description

	Annabessacook	Cobbossee	Pleasant
Morphometry			
Surface Area in hectares *(ac)*	575 *(1420)*	2243 *(5543)*	237 *(586)*
Mean Depth in meters *(ft.)*	5.3 *(17.4)*	8.1 *(26.5)*	2.7 *(8.8)*
Maximum Depth in meters *(ft.)*	14.9 *(49)*	30.5 *(100)*	7.9 *(26)*
Total Drainage Area in square kilometers *(mi^2)*	220 *(85)*	340 *(131.4)*	562 *(217)*
Direct Drainage in square kilometers *(mi^2)*	56.5 *(21.8)*	121.0 *(46.7)*	61.1 *(23.6)*
Residence Time *(days)*	81	304	65
Land Use Characteristics (% direct drainage area)			
Forest and Reverting Fields	69	65	73
Developed	12	11	8
Agriculture, Cultivated	16	20	16
Agriculture, Non-cultivated	1	0	1
Other	2	4	2

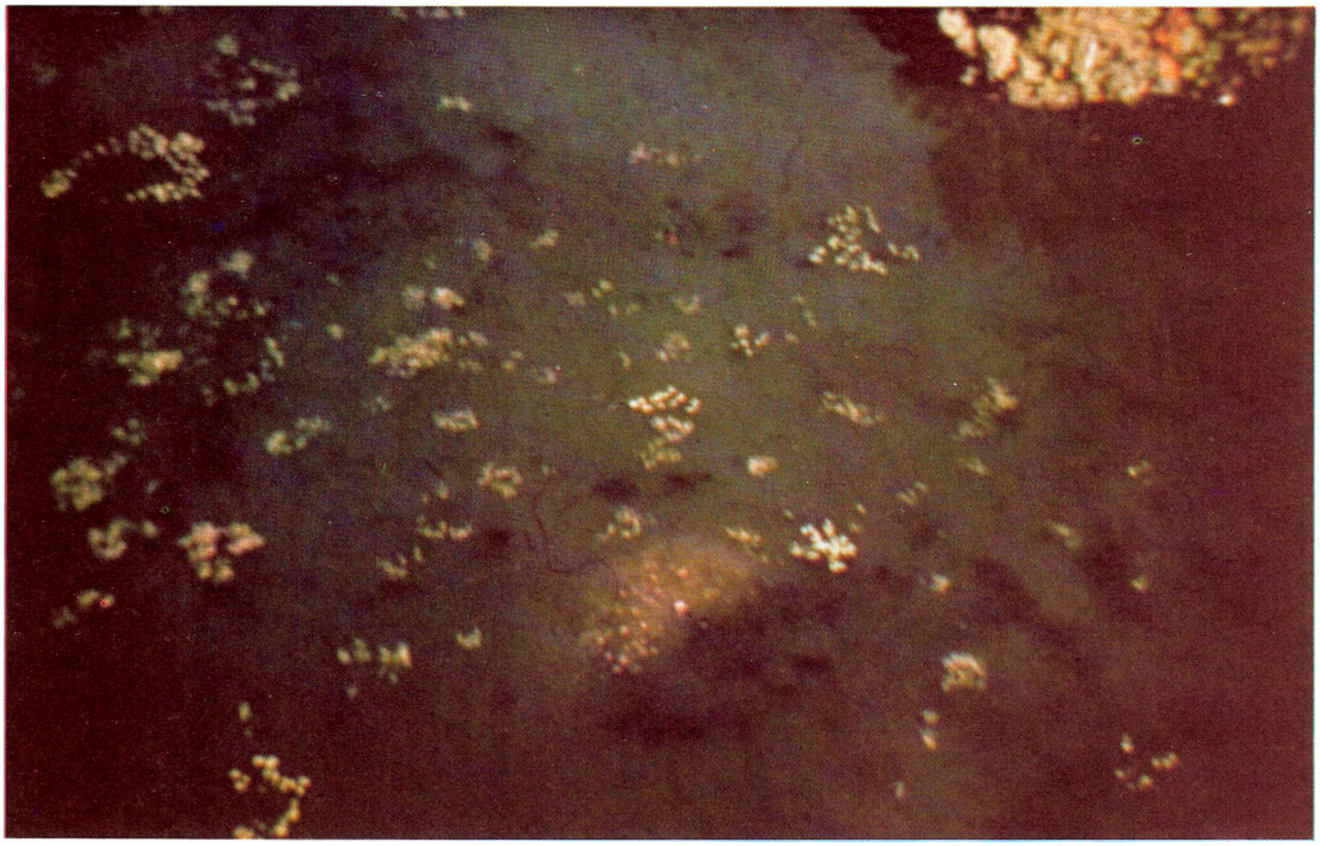
2. History of Restoration Efforts

Annabessacook Lake has long had the reputation as one of the most polluted lakes in the State of Maine. In the early 1940's, the first formal complaints of algae blooms on the lake were recorded. The lake became "pea soup" green every summer, often with thick scums of microscopic algae accumulating on the surface and heavy mats of leafy vegetation rotting on the shorelines. From 1964 through 1971, residents responded by treating Annabessacook with 30 tons of copper sulfate algicides, but the effect was short-lived and diminished with each season as resistant types of algae began to predominate.

Phosphorus is the nutrient controlling algal growth in most lakes of the northern United States and Canada, and for many years the industries and towns surrounding Annabessacook Lake discharged large quantities of phosphorus in their untreated wastes. These effluents stimulated the growth of algae in Annabessacook Lake and, subsequently, in Cobbossee Lake and Pleasant Pond downstream. Although numerous investigations of the lake were conducted, no action was taken to eliminate the discharges until 1970.

The first step toward lake restoration was elimination of the direct discharges of municipal and industrial effluent to Annabessacook Lake. In 1967, Maine's Water Improvement Commission found that Annabessacook Lake received

Weeds and Algae in Annabessacook Lake.



Algal Bloom in Annabessacook Lake.

over 13,600 kilograms (30,000 pounds) of phosphorus per year, and that the surface waters of the lake contained enough phosphorus to produce about 770,000 kilograms (1.7 million pounds) of algae. Municipal and industrial discharges from the village areas of Winthrop, North Monmouth, and Monmouth Center accounted for 93 percent of this annual phosphorus input.

To continue discharging into the lakes would have required costly advanced wastewater treatment to remove phosphorus. In 1969, the Augusta Sanitary District chose a more economical alternative and began building a trunkline sewer from Winthrop to the wastewater treatment plant in Augusta, a distance of approximately 19 kilometers (12 miles). The trunkline became operational in 1972 and was then extended, so that by 1976 all point source discharges of phosphorus to the Cobbossee Watershed lakes had been eliminated

Annabessacook Lake showed some improvement as a result of the diversion of point sources. However, the lake's ambient total phosphorus concentrations remained above 15 micrograms per liter ($\mu g/l$), the generally accepted threshold level for algal blooms in northern lakes. Continuing nuisance growth of algae in Annabessacook Lake, Cobbossee Lake, and Pleasant Pond indicated that the problem of cultural eutrophication had not yet been solved.

Hypolimnetic aerators were also installed in Annabessacook Lake in 1972 and 1974 in an effort to accelerate its recovery. The intent of the aeration project was to destratify the lake and mix the water layers, thereby reducing light penetration, cooling the epilimnion, and diluting the surface algal concentrations. It was determined that a simple aeration system could be set up by lakeshore property owners for summer use. However, the aeration project failed to mix lake water beyond a radius of 50 meters. Because of Annabessacook's size, the project did not reduce phosphorus levels in the water and may even have caused a net nutrient input by stirring up the phosphorus-rich sediments at the bottom of the lake.

Bottom sediments were a major focus of the early restoration plans. It was presumed that the bottom sediments were made up primarily of residues from the many years of sewage discharge into the lake. The shallow northern end of Annabessacook, the former discharge point for municipal and industrial effluent from Winthrop, was a particular focal point for concern. Bubbling water and foul odors caused by decaying vegetation, together with the proximity of the area to the old sewage outfalls, pointed toward this area as a significant source of nutrient loading continuing in the lake. However, sediment sampling indicated high nutrient levels over the entire lake bottom, not just the north end. Hopes of restoring the lake by dredging or marsh propagation in this restricted area disappeared.

Frustrated by 30 years of failure in improving water quality in the Cobbossee chain of lakes, lakeshore property owners, local officials, and concerned citizens began working to develop a strategy for lake restoration. Realizing that the causes of lake water pollution are most often found not within the lake itself, but rather in the various land use activities within the watershed that contribute pollutants through surface runoff or ground water, they formed the Cobbossee Watershed District in 1972. The District was designed to function as a quasi-municipal, special-purpose district, a governmental agency similar to a school district or sewer authority. In a watershed containing 14 major lakes and numerous tributary streams and ponds, with a land area of 620 square kilometers (240 square miles), it was hoped that this new unit of government could pursue a comprehensive approach which the 10 separate local governments could not.

The special-purpose lake district has several advantages for the resolution of water quality problems:

- Jurisdiction over the entire watershed, which extends beyond the boundaries of any single municipality;
- Taxation powers which free it from the competition for often limited tax revenues raised by a general-purpose government; and
- Specialized technical staff to deal with lake management problems and communicate with their counterparts in State and Federal agencies.

Since 1973, the District has been operated by a 13-member board of trustees, representing the municipalities and three water supply districts which joined. The District raises between $25,000 and $35,000 per year by local tax assessments to support its ongoing water resource programs.

3. Diagnostic Studies

In June of 1975, a Federal water quality management (208) planning grant enabled the District, in cooperation with Southern Kennebec Valley Regional Planning Commission, to undertake the detailed diagnostic studies needed to formulate a comprehensive restoration plan. They focused on determination of annual phosphorus loading budgets to the lakes.

Since the point sources of phosphorus had already been diverted, attention turned to loadings from non-point sources carried by overland runoff, atmospheric deposition, or diffusion from lake bottom sediments. The relationship of land use activities and phosphorus loadings was a critical linkage to be examined and defined. Comparison of present phosphorus budgets to present water quality and assimilative capacities, calculated using lake modeling techniques, would then allow assessment of needed phosphorus loading reductions. Determination of phosphorus contributions by various land uses and other non-point sources would lead to development of the most effective alternatives for achieving needed reductions.

The lakes were sampled every 10 days in 1975, from spring overturn (mid-April) to fall overturn (mid-October), for Secchi disc visibility and dissolved oxygen and temperature profiles. In 1976, the lakes were sampled biweekly from spring to fall overturn for Secchi disc visibility, chlorophyll-*a* and total phosphorus. Oxygen and temperature profiles were measured four times per year. Monitoring of the 12 major tributaries to Pleasant Pond and Cobbossee and Annabessacook Lakes occurred monthly during base flow conditions (July through August, December through March) and weekly to biweekly during spring and fall runoff periods (April through June, September through

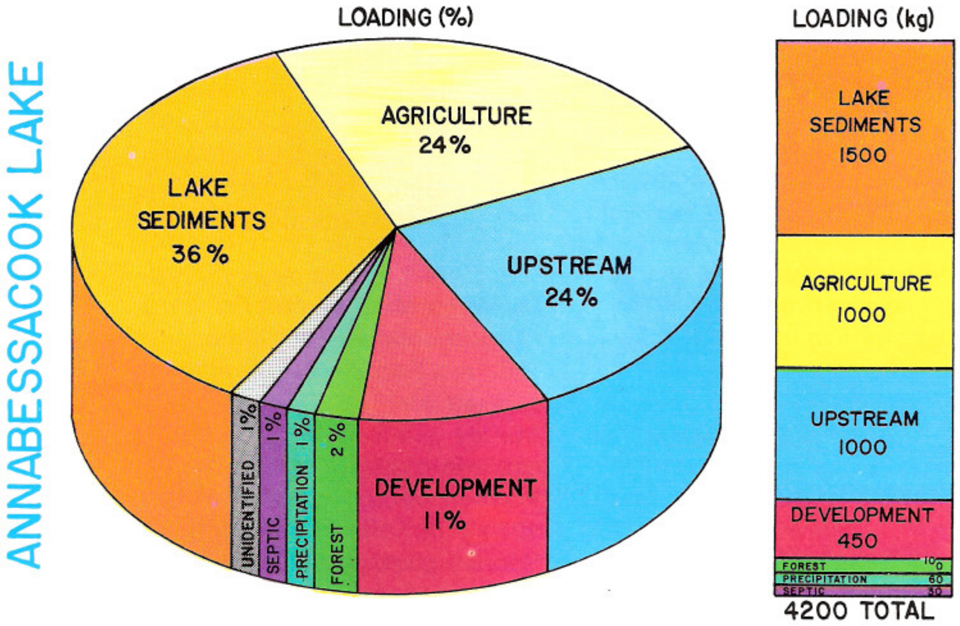


Figure 2a. Annabessacook Lake Phosphorus Sources.

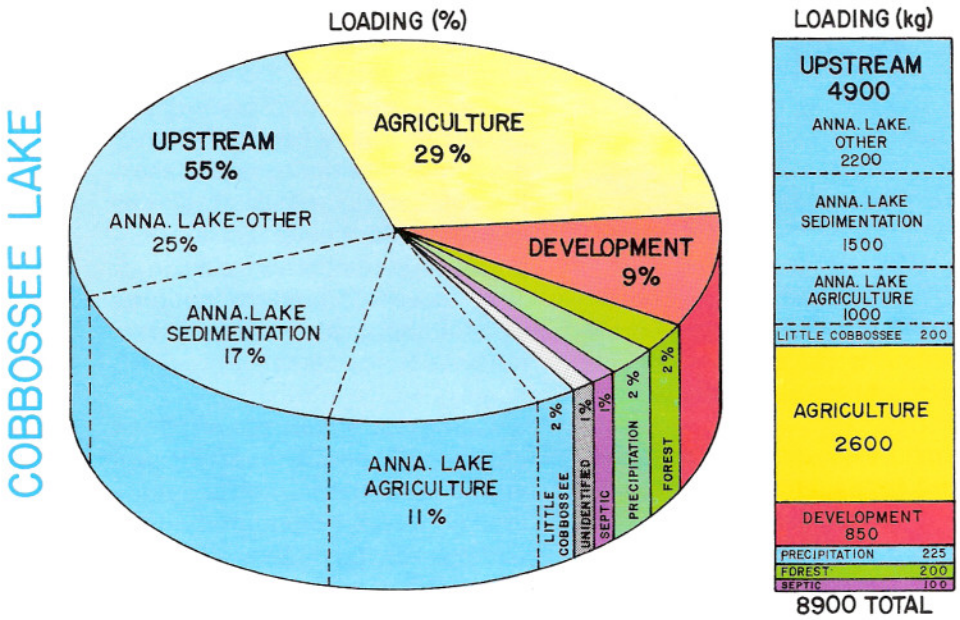


Figure 2b.
Cobbossee Lake Phosphorus Sources.

November). Parameters monitored included flow, total phosphorus, ammonia nitrogen, total Kjeldahl nitrogen, nitrate-nitrite nitrogen, dissolved oxygen, turbidity, suspended solids, and total coliform bacteria.

Morphometric data on the lakes were calculated from Maine Fish and Game Department lake surveys and U.S. Geological Survey quadrangle maps. Land use information was obtained from air photo interpretation of 1974 U.S. Soil Conservation Service photographs of the lake drainages.

Information on shoreline waste disposal systems, suspected as a primary contributor to lake degradation, was obtained through a door-to-door survey initiated by the Watershed District in 1974 and completed during the 208 diagnostic studies in 1975.

Phosphorus budgets were developed from the monitoring data to help in determining land use – water quality relationships (Figure 2). The phosphorus budget studies gave new insight to the lakes' problems. Shoreline septic systems, once considered a significant contributor to lake degradation, were found to contribute less than 1 percent of the phosphorus loading to the lakes. Internal recycling of phosphorus from lake bottom sediments was confirmed as the major phosphorus source (34 percent) and primary impediment to Annabessacook Lake's improvement and, as suspected, phosphorus-enriched water discharged from Annabessacook Lake contributed a majority of the total phosphorus loading to Cobbossee Lake, directly downstream.

The most surprising conclusion of the phosphorus budget studies was the identification of agriculture as a significant problem. Runoff from agricultural lands comprised the greatest single source of phosphorus to Pleasant Pond and the second most significant phosphorus source for Annabessacook and Cobbossee Lakes. The major agricultural

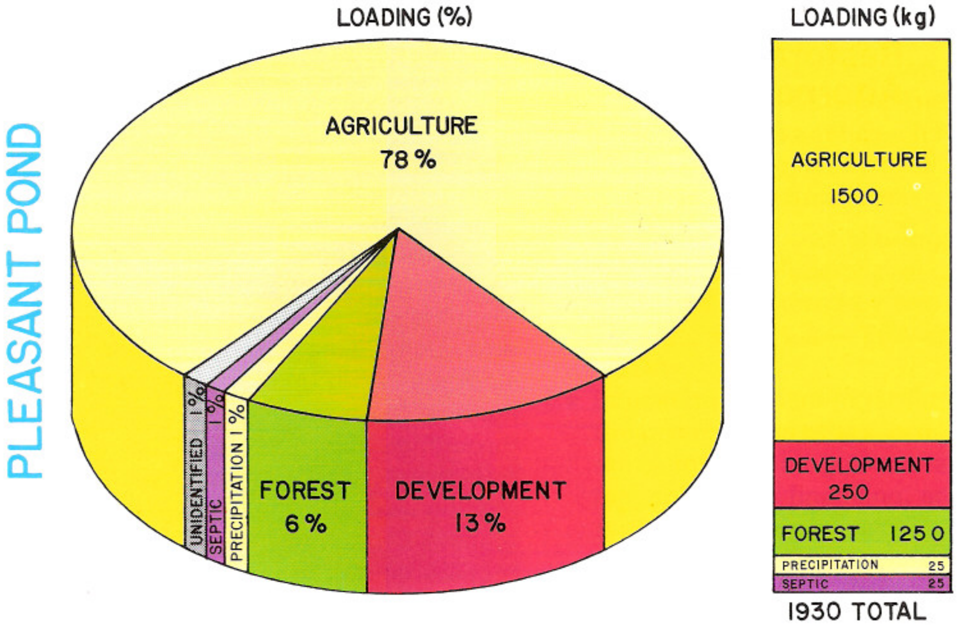


Figure 2c. Pleasant Pond Phosphorus Sources.

activity in the watershed is dairy and poultry farming, and the widespread practice of spreading manure on frozen and snow-covered ground was found to be the cause of the problem. Measurements of the phosphorus loss from agricultural lands showed that 65 to 70 percent of the loss occurred in the winter period from November through April.

Having calculated annual phosphorus budgets for each of the three problem lakes, phosphorus loading reductions needed to restore water quality had to be determined. This required defining water quality goals and standards. The primary goal established was to reduce productivity in the lakes, i.e., algal growth, to achieve acceptable water clarity. Regression analysis of three years of phosphorus concentration, chlorophyll-*a*, and Secchi disc visibility data from 26 lakes indicated that if phosphorus loadings could be reduced to achieve an overturn phosphorus concentration of 15 μg/l, algal productivity could be kept to acceptable levels and summer Secchi disc visibility would average 4.3 meters. The District therefore defined a minimum standard of 15 μg/l overturn total phosphorus for its lakes. Its strategy for lake restoration, however, was to endeavor to achieve average overturn phosphorus concentrations of 12 μg/l. In 1976 the average spring and fall overturn phosphorus concentrations in Annabessacook Lake, Cobbossee Lake, and Pleasant Pond were 30 μg/l, 18 μg/l, and 21 μg/l, respectively.

Using the Dillon-Rigler lake model, calculations were made regarding the maximum annual phosphorus loadings which could be received by the lakes without exceeding phosphorus concentrations of 12 μg/l, i.e., their assimilative capacities. These were then compared to the loadings estimated in 1976 to quantify needed reductions. The results indicated necessary loading reductions of 2,050 ± 250 kg for Annabessacook Lake; 3,100 ± 500 kg for Cobbossee Lake; and 600 kg for Pleasant Pond.

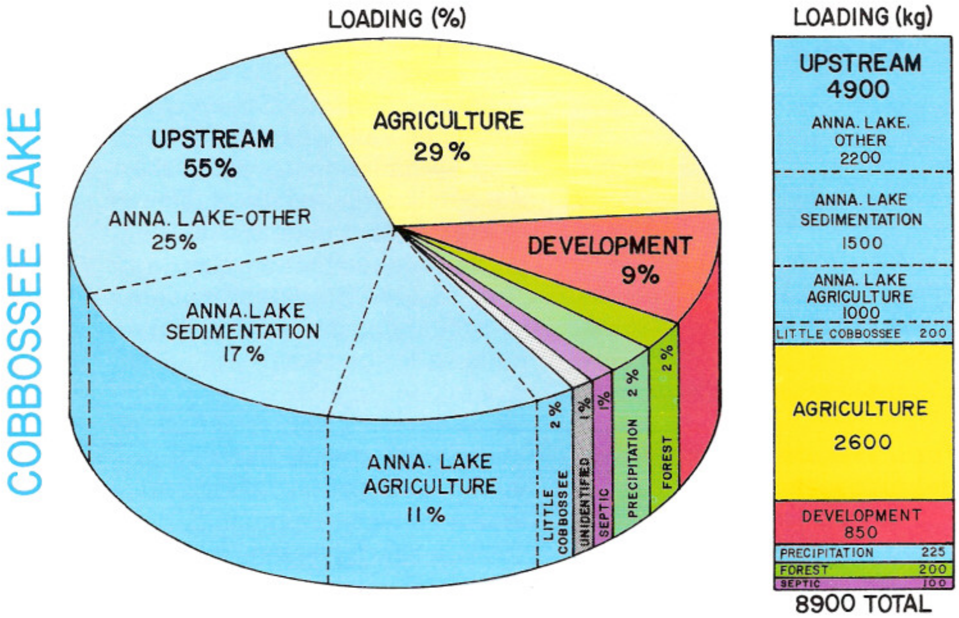


Figure 2b.
Cobbossee Lake
Phosphorus Sources.

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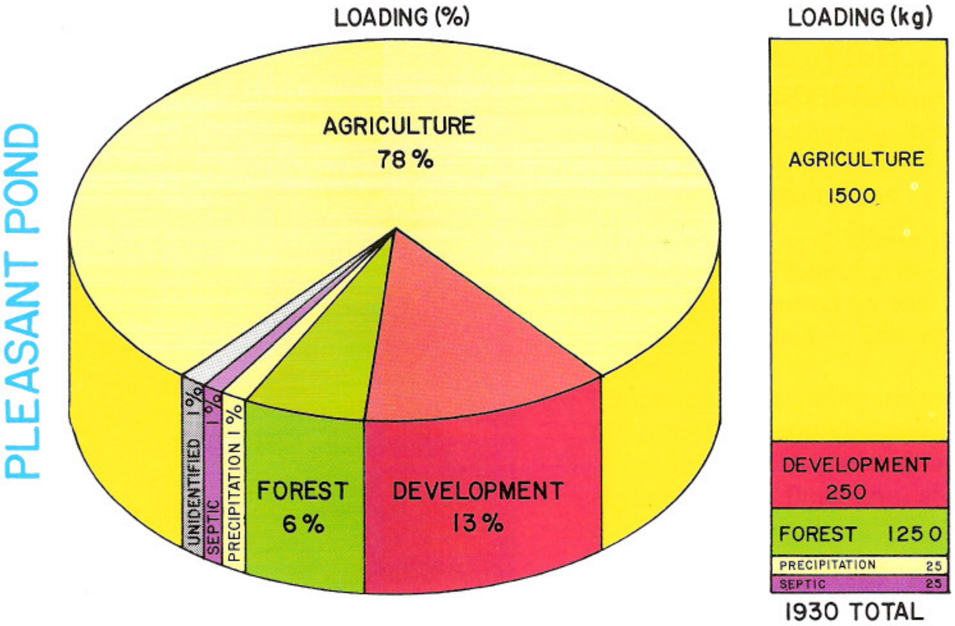

Figure 2c.
Pleasant Pond
Phosphorus Sources.

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4. Evaluation of Restoration Alternatives

Agricultural runoff and internal phosphorus recycling contributed 60 percent of the total phosphorus load to Annabessacook Lake. Cobbossee Lake received 28 percent of its load from agriculture in its direct drainage and 28 percent from agriculture and internal loading originating in the Annabessacook Lake drainage. Pleasant Pond received as much as 75 percent of its total phosphorus loading from agricultural drainage. If internal loading in Annabessacook Lake could be eliminated and agricultural sources reduced by 50 percent in all three lake drainages, estimates showed that the phosphorus concentrations in the lakes should be reduced to below the critical 15 $\mu g/l$. Consequently, those sources, rather than the smaller and more difficult to control contributions from septic systems and developed areas, were selected as restoration targets.

Phosphorus loading from agricultural sources could be reduced with proper management of manure, primarily through stopping winter spreading practices. Convincing farmers to stockpile rather than spread manure could be accomplished through two approaches: Financial incentive, by offering cost-sharing assistance for winter manure storage facilities; or regulation, requesting enforcement of Maine pollution laws prohibiting the direct or indirect discharge of animal wastes to State waters.

A survey of farmers in the three lake drainages revealed that most would have severe management problems if forced to stockpile manure without an engineered storage facility. The high cost of these facilities, from $10,000 to $40,000, had prevented their construction, since dairy farmers cannot easily pass on such added costs to the consumer. However, most farmers expressed interest in a cost-sharing program which would reduce their cost by 50 percent or more. Section 314 of the Federal Water Pollution Control Act was identified as a means of providing 50 percent cost-sharing. The Agricultural Stabilization and Conservation Service also could contribute $2,500 per farm. The District therefore decided to approach agricultural controls through financial incentive.

Several techniques were reviewed as alternatives for the control of internal phosphorus recycling, including:

- Dredging
- Selective Discharge
- Lake Bottom Sealing
- Hypolimnetic Aeration
- Nutrient Inactivation.

It was determined that dredging was not cost-effective and could even increase phosphorus availability. The use of selective discharge would aggravate the condition of Cobbossee Lake immediately downstream. Lake bottom sealing and hypolimnetic aeration were considered impractical considering the size of the lake. Only nutrient inactivation appeared both feasible and potentially effective.

Nutrient inactivation involves chemically treating a lake with agents which adsorb or chemically bond to soluble phosphorus and remove it from the water column through precipitation. Although relatively new as a lake restoration technique, it is essentially an extension of existing wastewater and water supply treatment technologies. Several agents have been investigated by lake research scientists, including zirconium and lanthanum rare earth elements, fly ash, iron, calcium and aluminum. Except for aluminum, all of these were judged to have serious limitations due to toxicity or incompatibility with the pH levels found in Annabessacook Lake bottom waters. Aluminum compounds appeared to be the ones most likely to effectively remove phosphorus under conditions found in the lake, retain phosphorus in the sediments following precipitation, produce little adverse effect on aquatic life, and be effective in the quantities the District could afford.

Manure Containment Structure.

5. Implementing the Agriculture Waste Management Program

The primary objective was to prevent spreading of manure on frozen or snow-covered ground. In Maine, this necessitates storage capacity for a 6-month accumulation.

For most farms, winter storage of manure meant a drastic change in the entire manure handling system — the containment structure, barn-to-storage transfer mechanism, and removal and application equipment. To assist farmers in making these costly and complicated changes the Cobbossee Watershed District recognized that a combination of skills would be required in a coordinated effort of local, State, and Federal agencies interested in furthering good farm management practices for the purpose of improving water quality. The effort included financial help from several agencies — U.S. Environmental Protection Agency, U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service and Farmers Home Administration — as well as technical assistance from others — Cobbossee Watershed District, USDA Soil Conservation Service, Kennebec County Soil and Water Conservation District, and the University of Maine Cooperative Extension Service. The activities of these agencies had to be coordinated in performing a wide variety of functions.

- Coordinating a cost-sharing program with Federal programs administered by two separate agencies — EPA and USDA
- Educating farmers regarding the project's purposes, procedures for obtaining cost-sharing, sources of financing, and availability of technical assistance
- Developing farm management plans including design of structural pollution controls, stipulation of manure application rates and timing, and delineation of stream corridor buffer zones
- Securing the cooperation and participation of the farmers
- Assisting farmers in obtaining contractors and materials
- Assisting contractors in meeting construction specifications
- Inspecting construction projects to ensure compliance with specifications

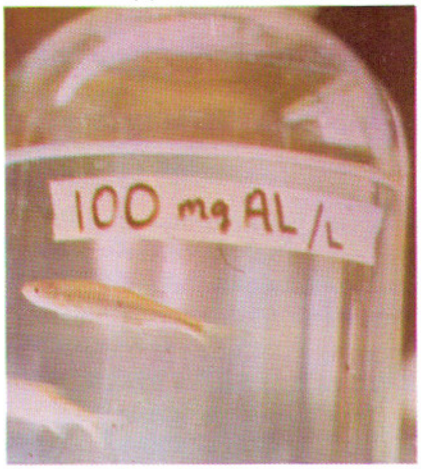
Through the long-standing Federal Agricultural Conservation Program, the Agricultural Stabilization and Conservation Service could offer farmers a maximum of $2,500 toward a conservation practice. In 1979 the limit was raised to $3,500. This alone had not been sufficient assistance to enable farmers to construct needed manure storage facilities and other pollution control practices. However, when this program was combined with 50 percent cost-sharing available through the EPA section 314 Clean Lakes Program, the resulting financial

Table 2.

Typical Manure Storage Facilities and Costs (1978)

TYPE FARM	MANURE SYSTEM COMPONENTS	TOTAL COST	FARMER'S SHARE
DAIRY	50′ x 80′ x 10′		
	Concrete Storage	25,700.	
90 milkers	with push-off ramps	2,000.	
20 youngstock	and roof	9,200.	
freestall	Equipment	3,100.	
		$40,000.	$17,500.
DAIRY	40′ x 40′		
28 milkers	Asphalt Pad with	1,200.	
20 youngstock	8′ Concrete headwall	6,400.	
stanchion	and earth sides	1,800.	
	Equipment	4,400.	
		$13,800.	$ 4,400.
DAIRY REPLACEMENT	37′ x 37′ x 4′		
20 animals	Concrete storage	4,850.	
stanchion	Asphalted barnyard	2,100.	
	Runoff controls		
	holding basin	450.	
	450′ diversion	1,500.	
POULTRY LITTER		$ 8,900.	$ 1,950.
STACKING SITE	40′ x 40′		
Broilers, 20,000	Concrete Pad	2,900.	
	with earth berms	3,100.	
		$ 6,000.	$ 500.

Bioassay Prior to Alum Application.



assistance package became significant and attracted the immediate interest of most farmers in the watershed.

Development of animal waste management plans which would meet the pollution control objectives of the Watershed District without exceeding management and financial constraints of the farmers was one of the most challenging aspects of the project. The restoration project combined the expertise of the existing agricultural assistance agencies and the Cobbossee Watershed District. The Soil Conservation Service provided standard engineering designs for diversions, earthen lagoons, and concrete containment structures, which were modified by the Cobbossee Watershed District to maximize pollution control. Watershed District and Kennebec County Soil and Water Conservation District personnel then worked intensively with farmers in preparing alternative plans for manure handling and runoff controls and in soliciting cost estimates from contractors. Once a design was selected, SCS engineers reviewed it and then inspected and certified all structural controls, while the local SCS conservationists drew up appropriate management plans.

Convincing the farmers to participate voluntarily in the program was critical to the success of the project. The farmer's share of costs ranged from $500 for small-scale poultry manure stacking sites to $20,000 for some large dairy farms (Table 2). Over half of the dairy farmers faced a minimum investment of their own funds of $5,000, and one-third were asked to invest in excess of $10,000. Consequently, it was necessary to demonstrate to the farmers not only the pollution control benefits, but also the benefits to farm productivity and farm management.

By June of 1980, 27 out of 35 farms targeted for controls in the project area had completed needed manure management facilities and runoff controls, while an additional four had initiated projects to be completed in 1980. The total cost of these controls was $627,000, of which EPA contributed one-half, ASCS $85,000, and the farmers the remainder. These 27 farms represented the major part of the animal waste problem; they originally generated 78 percent of the phosphorus attributed to livestock manure in the watersheds of the three eutrophic lakes. However, the water quality effects of this success will not be fully evident for another 2 to 3 years, since the lakes respond to decreases in phosphorus loading over a period of time. Extensive lake and tributary monitoring programs are continuing to assess results.

6. Nutrient Inactivation Treatment

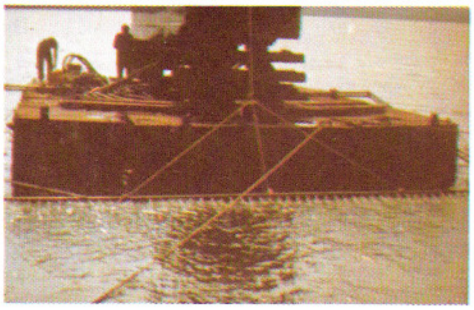
Prior to implementation of nutrient inactivation treatment, bioassays and a feasibility study were conducted to determine the optimum application rates of aluminum sulfate. This was a function of:

- Phosphorus removal efficiency
- Residual dissolved aluminum concentrations
- Flow formation characteristics
- Change in pH
- Potential toxicity to biota.

To prevent harm to aquatic life, sodium aluminate was used in the treatment as a buffer to counteract the potential change in lake pH caused by alumunum sulfate. Bioassays were also conducted to determine the potential toxicity of the treatment to fish and invertebrates. After testing various combinations of the two chemicals, an

Chemical Storage.

Chemical Application Barge.



Alum Application.

alum-to-aluminate ratio of 1.6:1.0 was selected. This ratio produced excellent phosphorus removal (at least 98 percent), minimal change in pH, and little residual aluminum.

Lake bottom sediments are usually regarded as a "sink" for phosphorus. Generally, when phosphorus is incorporated in the bottom sediments, it becomes unavailable for stimulating algal growth. However, when the lake's hypolimnion becomes anerobic, significant amounts of phosphorus may be released from the sediment and circulated through the lake.

The area of anoxia increases with time during the period of stratification. Thus, to define the area of the lake in greatest need of nutrient inactivation treatment, detailed surveys of dissolved oxygen concentrations were conducted. The deepest area of Annabessacook Lake usually became anoxic in early June. By mid-August, all areas at least 7 meters deep became anoxic, an area of approximately 170 hectares (420 acres). The volume of anaerobic water to be treated was estimated at 3.5×10^6 cubic meters (920 million gallons). Thus, the logistics of the actual application were a major challenge to the project.

Based on the recommended application rates, approximately 227,000 liters (60,000 gallons) of aluminum sulfate and 142,000 liters (37,500 gallons) of sodium aluminate, with a combined weight of more than 455,000 kg (1 million pounds), would be needed to treat the lake effectively.

The treatment was carried out in August 1978, and required one month to complete. Chemicals were delivered daily by truck, stored in polyvinyl-lined swimming pools on shore, and transferred to a 22,700 liter (6,000 gallon) tank on the 12 m (40 foot) barge used for the chemical application.

Alum was diffused at a depth of 5.2 m (23 feet) into the hypolimnion at 15 centimeter (6-inch) intervals along a horizonal 8.8 meter (29-foot) length of iron pipe, which could be raised and lowered by a winch. Valves and flow meters allowed accurate regulation of discharge rate in relation to the speed of the barge.

As with the agricultural component of the project, coordination with other agencies and groups was an important aspect of the nutrient inactivation treatment process. The Watershed District received technical assistance from the Maine Department of Environmental Protection throughout the project. In addition, the Annabessacook Lake Inprovement Association and the Cobbossee Lake Yacht Club contributed funds, while lakeshore property owners and other interested citizens contributed many hours of labor, as well as the use of boats and property necessary for the storage of chemicals and supplies. The cost of the treatment is estimated at approximately $200,000 which included $62,500 for chemicals, equipment and barge rental.

7. Results

To date, the most significant response to the $935,812 restoration project has been seen in Annabessacook Lake. Best management practices have been applied to most of the agricultural operations in its drainage area. This, coupled with an apparently dramatic decrease in internal phosphorus loading following nutrient inactivation, has reduced total loading of phosphorus by an estimated 45 percent in comparison to 1975 conditions. Figure 3 shows the result in terms of midsummer total phosphorus concentrations at various depths in the deepest part of the lake.

From a lake user's viewpoint, the immediate benefit of the reduction in phosphorus loading and concentration has been the improvement in water clarity shown in Figure 4. Secchi disk depths were never less than 2.0 meters during the 106-day period for June 1 through September 15, 1979. Table 3 shows transparency data for corresponding periods at other significant times in Annabessacook's history.

As of early 1980, Cobbossee Lake has not had adequate time to respond to the improvements in the quality of water received from Annabessacook Lake. Furthermore, additional farm projects are planned for both the Cobbossee Lake and Pleasant Pond watersheds during the summer of 1980 to complete the necessary controls on manure runoff. The Cobbossee Watershed District and the Maine Department of Environmental Protection will continue to monitor these lakes through July 1981 to assess the results of the restoration program.

Figure 3.

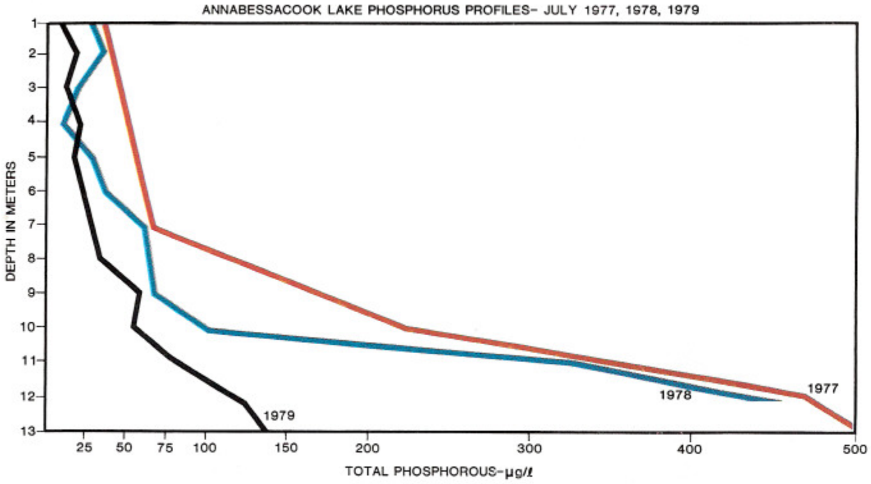


Figure 4.

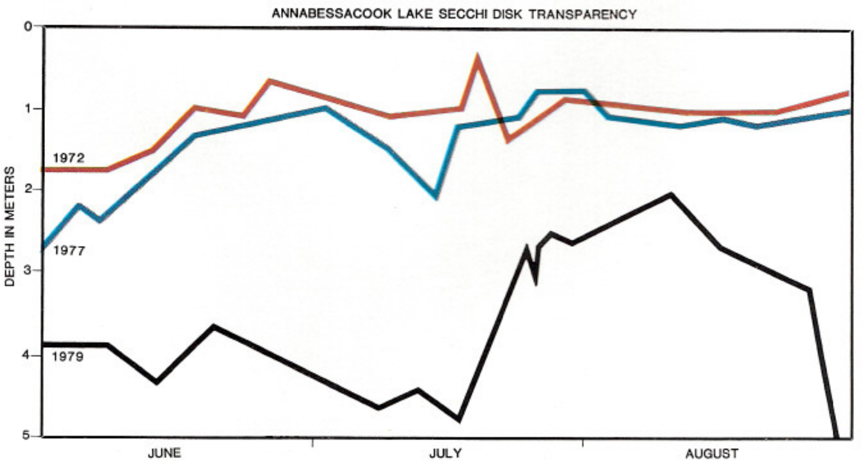


Table 3.

Annabessacook Lake Visibility.

Secchi Disk Depth	Public Perception of Water Quality	Days at Given Visibility (June 1 - September 15)		
		1972	1977	1979
0 - 0.9 meters	gross pollution; lake is totally unusable for recreation	43 days	10 days	0 days
1 - 1.9 meters	algae blooms still evident; quality is unacceptable for most uses	63 days	67 days	0 days
2 - 2.9 meters	some complaints of declining water quality; some impairment of water use	0 days	28 days	30 days
3 - 3.9 meters	satisfactory quality; no impairment of water use	0 days	1 day	40 days
4 - 4.9 meters	excellent water quality; a positive factor encouraging lake use	0 days	0 days	35 days
5 + meters	exceptional quality for this lake	0 days	0 days	1 day
		106 days	106 days	106 days

Notes on selected years:

1972 - prior to full diversion of municipal/industrial wastewater

1977 - prior to lakes restoration project

1979 - after agricultural waste controls and nutrient inactivation treatment

Annabessacook Lake After Nutrient Inactivation.

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This report has been reviewed by the Clean Lakes Section, Criteria and Standards Division, U.S. Environmental Protection Agency and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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