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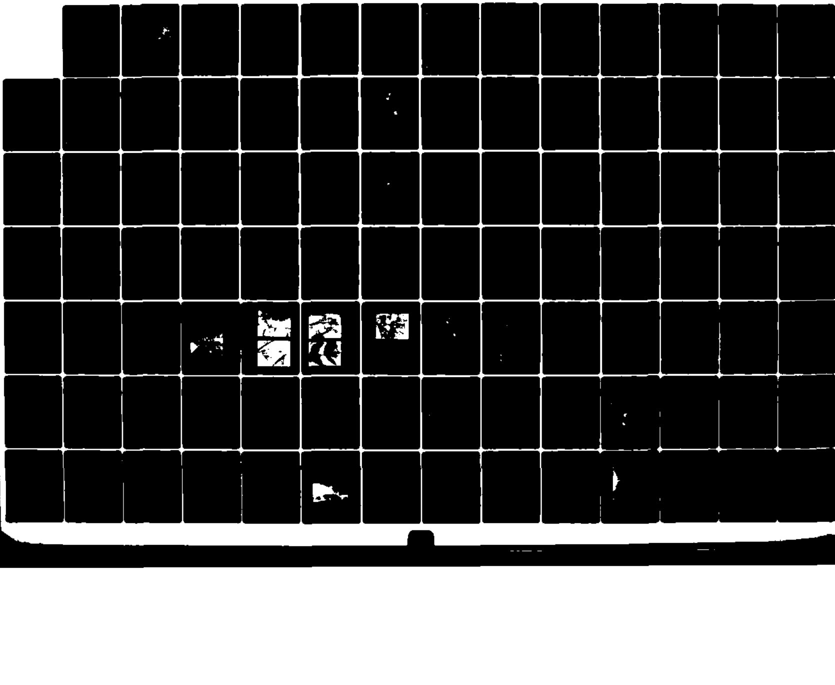

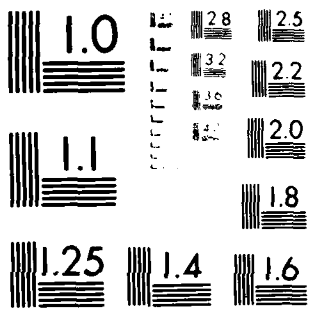

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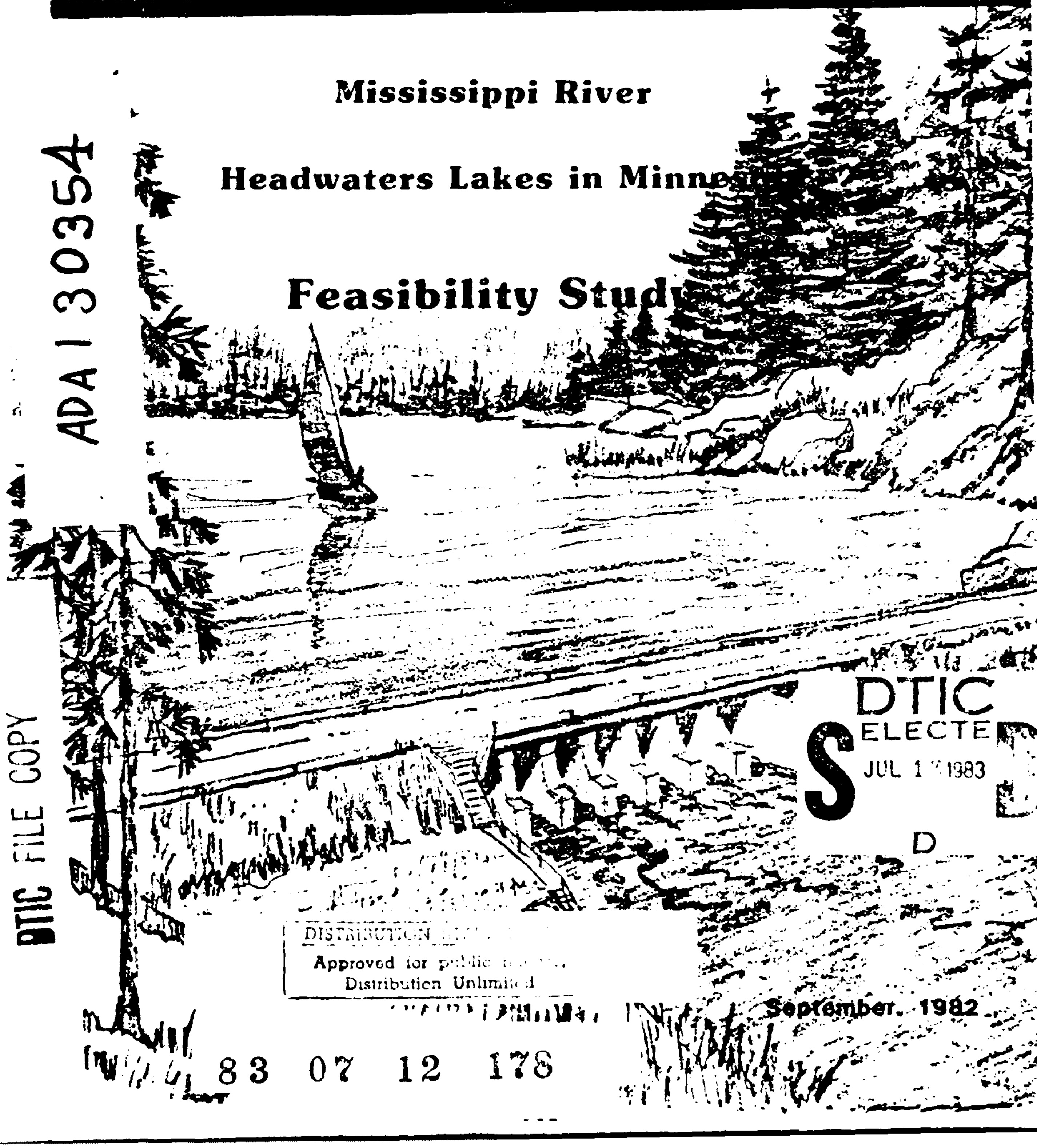
US Army Corps
of Engineers
St. Paul District

MAIN REPORT

Mississippi River

Headwaters Lakes in Minnesota

Feasibility Study



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MISSISSIPPI RIVER
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LAKES
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DAMS

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The investigation of six Mississippi River Headwaters Lakes: Gull Lake, Leech Lake, Pine River, Pokegama, Sandy and Winnibigoshish, centers on all water resource problems involving the operation of the Corps' dams. The study includes a review of lake operation plans for flood control, water supply, recreation, navigation, power, and conservation; review of erosion control problems downstream of Pokegama dam; review of bank erosion; a feasibility study of stabilized White Oak Lake water levels on the Mississippi River upstream of Pokegama and Leech Lake River; a review of flood

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) problems near Riverton, Minnesota; a hydrologic review of the existing headwaters lakes perimeter diking system; a feasibility study of removing channel obstructions on the Whitefish Lakes Chain; a study of the adequacy of the Leech Lake inlet channel; a review of a possible subimpoundment in Leech lake and marsh restoration; and a review of the adequacy and effectiveness of the existing flood control project for Aitkin, Pine Knoll and Cedar Brook.

The main report is a general, nontechnical presentation which evaluates selected problems, summarizes costs and benefits and other impacts of each alternative, and makes recommendations for further study.

SYLLABUS

This report contains an analysis of alternative solutions to previously identified water related problems connected with the operation of the six Mississippi River Headwaters Lakes. Between 1881 and 1913, the Corps of Engineers constructed six water control dams at the outlets of these once natural lakes. The original purpose of the dams was to improve navigation and provide some minor benefits to logging.

The need for water releases from the six lakes to aid navigation was greatly reduced by completion of a 9-foot navigation channel below Minneapolis, Minnesota, in the 1930's. The six lakes have subsequently been used more and more for recreation, fish and wildlife, and flood control purposes. Upstream and downstream interests are deeply concerned about the judicious use of these lakes.

This report's summary recommendations for the 10 water related problems identified for study are as follows.

Problem area	Recommendation
Headwaters lakes operating plans	The present operating plan should be retained in accordance with the Department of Army Regulations now in effect. The recommended plan should incorporate conservation features for Winnibigoshish and Leech Lakes which are currently under an extended 5-year trial operation.
Bank erosion control on six headwaters lakes	No economically feasible solution could be identified. No further study is recommended.
Erosion problems downstream of Pokegama Dam	No economically feasible solution could be identified. The problem is caused by natural processes. No further study is recommended.

Problem area	Recommendation
White Oak Lake water levels	The Minnesota Department of Natural Resources is adamantly opposed to this proposal. No further study is recommended.
Black Bear and Miller Lakes flood problem	A small closure structure or levee is economically feasible and is being evaluated further under the small projects authority. No further action is recommended under the Mississippi River Headwaters Study.
Headwaters lakes perimeter dikes	These dikes should be further located, inspected, tested, and upgraded in the District's regularly scheduled maintenance program under present funding authority. However, any dike raise would require additional authority to implement.
Whitefish Lake channel obstructions and marking	An economically feasible project has been identified, but no proper local sponsor can be found. Further study can be done under Small Projects authority if a sponsor is found.
Leech Lake dam inlet channel restrictions	An economically feasible solution is proposed for completion under the District's regularly scheduled maintenance program under present funding authority.
Leech Lake cutoffs	No economically feasible proposal could be identified. No further study is recommended.
Aitkin area flood problems	No economically feasible solution could be identified. No further study is recommended.

STAGE 2 SUMMARY REPORT

MISSISSIPPI RIVER HEADWATERS LAKES STUDY

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THE STUDY AND REPORT

This study is a cooperative Federal, State, and local planning effort directed by the Corps of Engineers to develop a plan for the operation of the Mississippi River Headwaters Lakes. The water and related land resources in the study area have been developed primarily for navigation, flood control, hydroelectric power, water supply, recreation, and fish and wildlife enhancement. The six controlled lakes, natural lakes, streams, marshes, and national and State forests in the basin provide habitat for fish and wildlife and excellent opportunities for water- and land-based recreation. The lakes and marshy terrain afford a considerable amount of regulation of the river for flood control, power generation, and other beneficial uses. The study examines the water related problems and needs of the headwaters lakes operation and evaluates possible alternatives, giving consideration to environmental, social, and economic impacts.

PURPOSE AND AUTHORITY

At the request of local interests, the Committee on Rivers and Harbors of the House of Representatives passed a resolution on 7 June 1945, requesting a study of the six Mississippi River Headwaters Lakes: Winnibigoshish, Leech, Pokegama, Sandy, Pine River, and Gull Lakes. The study was to investigate navigation, flood control, water supply, water quality control, fish and wildlife, recreation, and other related areas. The resolution follows:

> "Resolved by the Committee on Rivers and Harbors of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors be, and is hereby, requested to review the reports on Mississippi River above Coon Rapids Dam near Minneapolis, Minnesota, submitted in House Document Numbered 66, Seventy-third Congress, first session, and previous reports,

with a view to determining if any modifications of previous recommendations with respect to navigation, flood control, and other purposes are advisable at this time, including consideration of the operation of the existing headwaters reservoirs in order to obtain the greatest possible benefits to all affected interests."

The overall study of the Mississippi River Headwaters area was initiated in 1945, but was not completed due to insufficient funding; however, an interim survey report was completed for a proposed dam near Days High Landing, Minnesota, in March 1972. No further major study work was conducted until 1976 when the overall study was reactivated. The overall study will include a review of the Days High Landing proposal which was never authorized by Congress. The March 1972 Days High Landing report was returned to the St. Paul District in 1975 for further coordination with the State of Minnesota.

SCOPE OF THE STUDY

The investigation of the six Mississippi River Headwaters Lakes[(1)] centers on all water resource problems involving the operation of the six Corps constructed dams. This study, however, is not restricted to the immediate headwaters area, but extends downriver to include the areas where specific uses are affected by the dam operations.

The study includes: (1) a review of lake operation plans for flood control, water supply, recreation, navigation, power, and conservation; (2) a review of bank erosion around the six headwaters lakes and downstream from Pokegama Dam; (3) a review of erosion control problems downstream of Pokegama Dam; (4) a feasibility study of stabilized White Oak Lake water levels on the Mississippi River upstream of Pokegama Lake and Leech Lake River below Leech Lake Dam;

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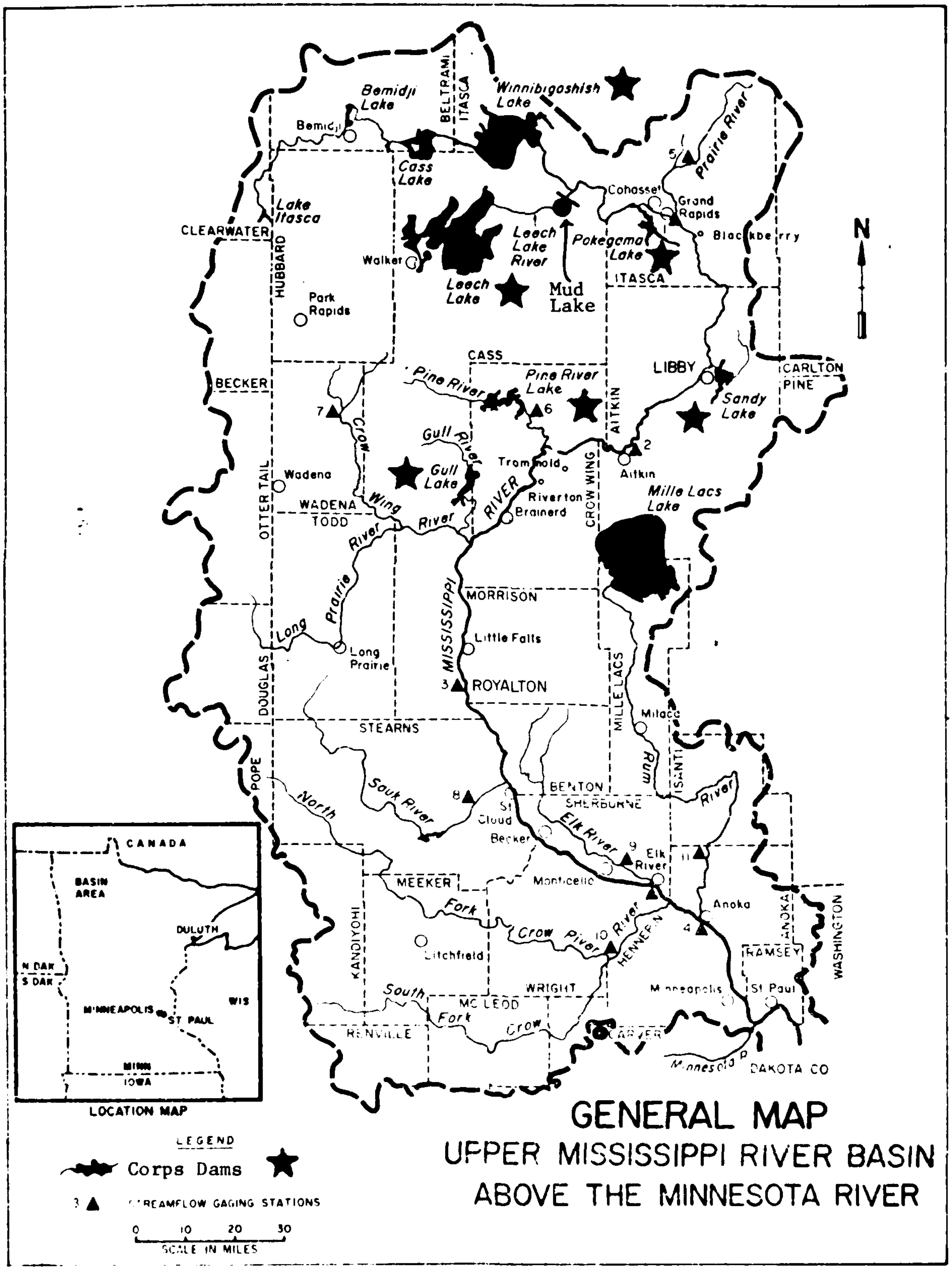
(1) Six Mississippi River Headwaters Lakes are controlled by dams constructed by the St. Paul District, Corps of Engineers. Prior to the 1970's these lakes were called "reservoirs." The former "Pine River Reservoir" which includes 12 separate lakes of the Whitefish chain will be referred to as "Pine River Lake."

(5) a review of flood problems near Riverton, Minnesota (Black Bear and Miller Lakes); (6) a hydrologic review of the existing headwaters lakes perimeter diking system; (7) a feasibility study of removing channel obstructions on the Whitefish Lakes Chain; (8) a study of the adequacy of the Leech Lake inlet channel; (9) a review of a possible subimpoundment in Leech Lake and marsh restoration on the Leech Lake River downstream of Leech Lake Dam; and (10) a review of the adequacy and effectiveness of the existing flood control project for Aitkin, Pine Knoll, and Cedar Brook.

A map of the Upper Mississippi River drainage area above the confluence with the Minnesota River is shown on the following figure.



GENERAL MAP
UPPER MISSISSIPPI RIVER BASIN
ABOVE THE MINNESOTA RIVER

STUDY PARTICIPANTS AND COORDINATION

Throughout the study, individual contacts are being maintained with local officials, regional planning agencies, city engineers and planners, local consulting engineers, mayors and council members, and county and city boards. Public participation in the decision-making process is encouraged through the availability of speakers, slides, and other material on the headwaters lakes study. Local publics and agencies providing direct support to the study include the following: the Mississippi River Headwaters Association, League of Women Voters, Izaak Walton League, Arrowhead and Region 5 Regional Development Commissions, Upper Mississippi River Basin Commission, Sierra Club, commercial and industrial groups, State university centers, and local civic and lake associations.

State agencies participating directly in the study include: the Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, State Planning Agency, and Metropolitan Council.

Federal agencies providing advice and input to the study include: the U.S. Fish and Wildlife Service, Soil Conservation Service, U.S. Geological Survey, U.S. Forest Service, Bureau of Indian Affairs, National Park Service, Heritage Conservation and Recreation Service, Environmental Protection Agency, Federal Insurance Administration, and Federal Energy Regulatory Commission.

Coordination for the study was maintained directly between the study manager, the Mississippi River Headwaters Association, a Federal-State agency steering committee, and groups of people interested in the specific areas of study. For example, direct contact was maintained with the St. Paul and Minneapolis Water Departments, Metropolitan Sewer Board, city of Aitkin, power companies, Black Bear and Miller Lakes residents, Blackberry area residents, Leech Lake Indian Tribe, and regional development commissions. The contact included meetings, telephone calls, letters, and progress reports.

THE REPORT

The report consists of a main report and supporting appendixes. The main report is a general, nontechnical presentation of the Mississippi River Headwaters Lakes Feasibility Study. The main report evaluates selected problems, looks at alternatives to solving those problems, summarizes costs and benefits and other impacts of each alternative, and makes recommendations for further study.

The supporting appendixes provide greater detail on the development of the alternatives and on specific study aspects and include pertinent correspondence relating to study coordination activities among Federal, State, and local interests. Study progress reports detailing public involvement for the study are also included.

PRIOR STUDIES AND REPORTS

Prior studies and reports on examinations and surveys of the Mississippi River in northern Minnesota date back to 1870. The earlier reports deal primarily with navigation and include headwaters lakes surveys and channel examinations. Some of the more pertinent studies and reports are summarized on the following pages with those contained in House Documents noted by reference.

a. A report contained in House Document No. 113, 56th Congress, 2d Session, covers a survey and investigation to determine the causes of excessive flooding, the subsequent effect on navigation, and the means of preventing such flooding in the Mississippi River valley between the Federal dam at Sandy Lake and Brainerd, Minnesota. The report, dated 30 November 1900, was submitted in compliance with the requirements of the River and Harbor Act of 3 March 1899 and covered possible means of reducing flood damages by levees, cutoff channels, and channel improvement. No recommendations were included in the report.

b. The annual report of the Chief of Engineers for 1906, pages 1458-1464, discussed the flood situation at Aitkin with particular reference to the operation of the headwaters lakes, concluding that the Aitkin area had been benefited, never adversely affected, by lake operation. Particular mention was made of the serious situation created by the 1905 flood and possible solutions of the problem were outlined, but the report did not recommend that the Federal Government undertake the work.

c. The report of the Board of Engineers for Rivers and Harbors, dated 5 November 1906 (House Document No. 42, 61st Congress, 2d Session), supplemented the 30 November 1900 report in House Document No. 113. The advisability of expanding lake control for flood protection in the vicinity of Aitkin was suggested since it would also benefit navigation, but no lake change was recommended. Levee construction by local interests was mentioned as a possible means of protection.

d. Reports dated 1 September 1909 and 18 December 1909 are contained in House Document No. 607, 61st Congress, 2d Session. The reports recommended improvement of 181.5 miles of the Mississippi River between Grand Rapids and Brainerd, Minnesota, by dredging, wing dam construction, and removal of snags. The purpose of the project was to provide a 3½-foot channel in this portion of the river.

e. House Document No. 282, 62d Congress, 2d Session, contains a preliminary examination of the Mississippi River, dated 5 October 1911, with a view to removal of a ledge in Aitkin County at or near Pine Knoll. The report states that a cut in the riverbed averaging about 5 feet in depth over a distance of about 7 miles below Pine Knoll might prove more effective in reducing floods than the methods suggested in earlier reports. However, the report concluded that improvement of the channel for flood control was not the responsibility of the United States and that any improvement required for navigation was within the scope of a previously authorized project.

f. Reports dated 7 January and 14 December 1911 are contained in House Document No. 1223, 62d Congress, 3d Session. The reports recommended straightening and improvement of the Mississippi River channels between Winnibigoshish and Pokegama Lakes and from Leech Lake Dam to the mouth of the Leech Lake River. This improvement, authorized under the 1913 River and Harbor Act and completed in 1926, was to provide for more efficient transmission of water from the upstream lakes to Pokegama Lake Dam, and ultimately downstream, in the interest of navigation below Minneapolis.

g. A report dated 13 January 1913 is contained in House Document No. 243, 63d Congress, 1st Session. This report recommended against construction of navigation locks in the Mississippi Headwaters dams of Winnibigoshish, Leech, and Pokegama Lakes.

h. A report considering flood conditions in the Aitkin area is contained in House Document No. 66, 73d Congress, 1st Session. The report, dated 24 May 1933, is a survey in accordance with provisions of House Document No. 308, 69th Congress, 1st Session, and in agreement with the provisions of Section 1 of the River and Harbor Act of 21 January 1927 and Section 10 of the Flood Control Act of 15 May 1928. The report deals with navigation, flood control, power, and irrigation on the Mississippi River above Coon Rapids Dam, Minnesota. At that time the most feasible plan of improvement found for the Aitkin area included channel improvement and controlled lake operation in the interests of flood control and navigation. The report concluded that the flood problem at Aitkin was essentially local, the floods affected only a small area and had no widespread economic effect, and there was no interest to justify participation by the United States at that time.

i. A report dated 15 April 1946 is contained in House Document No. 599, 80th Congress, 2d Session. The report recommended flood control improvement in the Aitkin vicinity by means of a flood diversion channel. The project was economically justified and was subsequently authorized for completion by the Flood Control Act approved 30 June 1948.

j. A report entitled "Flood Control Definite Project Report on Mississippi River near Aitkin, Minnesota, February 1952" was subsequently prepared. The report recommended a project for improvement of the Mississippi River near Aitkin in the interest of flood control. The project was constructed during the period August 1952 to June 1956.

k. A computer study to develop operation plans for the headwaters lakes was initiated in November 1962 and completed in November 1964.

l. A water resources study was prepared for the Department of Health, Education and Welfare to determine present and prospective needs and values of storage in the headwaters lakes for water uses in the Minneapolis-St. Paul area. The study was initiated in February 1962 and completed in December 1964.

m. A report entitled "Feasibility Study, Restoration of Water Levels along Leech Lake River below Federal Dam, Minnesota, 9 August 1966" found that restoration of a 4-mile portion of Leech Lake River downstream of Leech Lake Dam was economically feasible. The report recommended further detailed studies as a part of the overall headwaters lakes study.

n. A report entitled "Interim Survey Report, Mississippi River above Coon Rapids Dam near Minneapolis, Minnesota, Days High Landing Dam, Minnesota, 21 March 1972" recommended construction of a dam and lake on the Mississippi River at Days High Landing. The purpose of the project was to raise and stabilize water levels in the White Oak Lake area in the interests of wild rice production and fish and wildlife propagation.

o. A report entitled "Flood Plain Information, Mississippi River and Ripple River, Aitkin, Minnesota, June 1975" identifies the intermediate regional (100-year) and standard floodplains for a

14.8-mile segment of the Mississippi River in the Aitkin area. The report provides a basis for Aitkin to adopt floodplain ordinances and zoning restrictions in accordance with Minnesota Statutes, Chapter 104.

p. A report entitled "Upper Mississippi River Comprehensive Basin Study" was completed on 5 June 1972 by the Upper Mississippi River Basin Coordinating Committee. The report consists of a main report and 17 appendixes which summarize the water and related land resources and further development potential of the Mississippi River basin above the Ohio River. The study presents the water and related land resource needs and a framework for developing those resources.

RESOURCES AND ECONOMY OF THE STUDY AREA

An understanding of the resources and developmental trends of the study area is necessary to identify related problems and needs and to formulate solutions to these problems and needs. The following sections discuss natural and human resources as well as the development and economy of the study area.

ENVIRONMENTAL SETTING AND NATURAL RESOURCES

Study Area

The study area encompasses the Upper Mississippi River drainage basin above Minneapolis-St. Paul, Minnesota, about 19,400 square miles of land area.

Surface Water

An average annual runoff of approximately 4.5 inches occurs for both the 19,400-square mile Mississippi River Headwaters area above Minneapolis, and the 3,370-square mile incremental drainage area above Grand Rapids (including Winnibigoshish, Leech, and Pokegama Lakes).

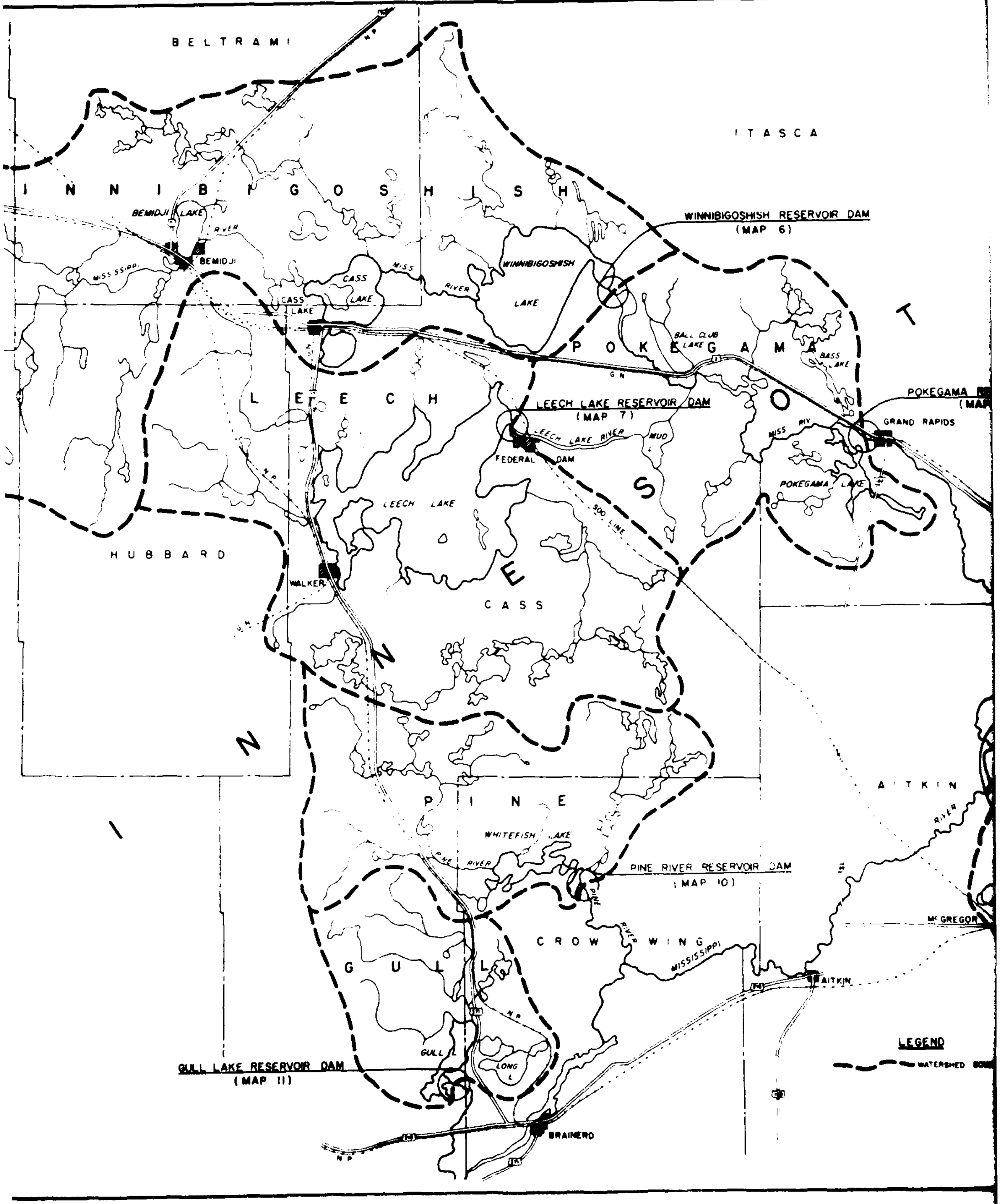
The many lakes and marshes in the basin combined with the controlled headwaters lakes provide a large amount of storage, a factor that prohibits rapid runoff. Runoff extremes ranging from approximately 1.1 to 11.7 inches have been recorded. The months with the highest rates of runoff are usually March through June. The average slope of the river above Minneapolis is about 2.5 feet per mile.

The contributing drainage area upstream of the six headwaters lakes is summarized in the following table and accompanying figure.

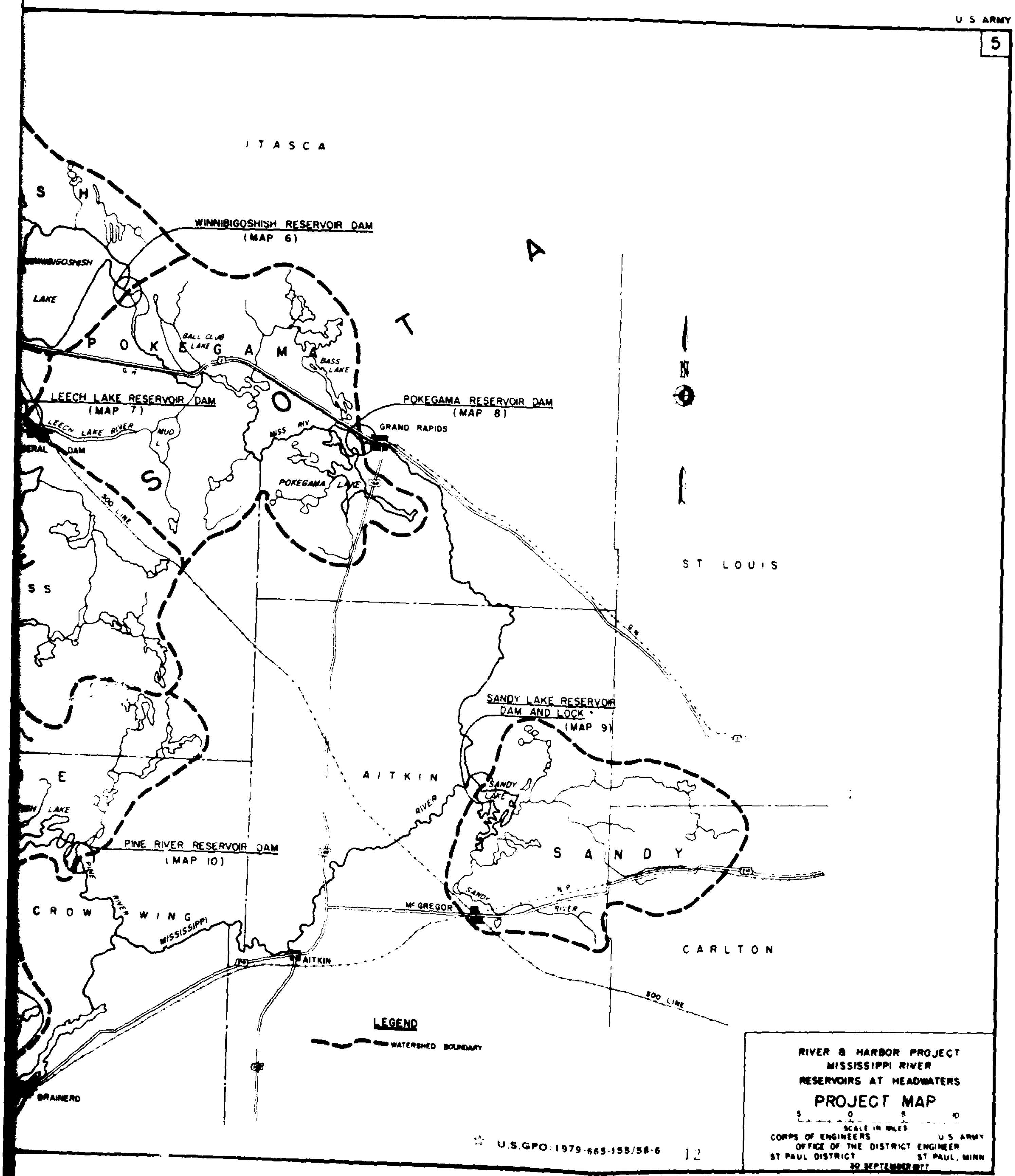
Mississippi River Headwaters Lakes contributing drainage area

Lake	Contributing drainage area (square miles)
Winnibigoshish	1,442
Leech	1,163
Pokegama (1)	660
Sandy	421
Pine River	562
Gull	287
Total	4,535

(1) Total of 3,265 square miles above Pokegama Dam.



BELTRAMI
ITASCA
WINNIBIGOSHISH
BEMIDJI LAKE
RIVER
MISSISSIPPI
BEMIDJI
CASS LAKE
CASS LAKE
MISS RIVER
WINNIBIGOSHISH LAKE
WINNIBIGOSHISH RESERVOIR DAM
(MAP 6)
POKEGAMA
BALL CLUB LAKE
BASS LAKE
G N
LEECH
LEECH LAKE RESERVOIR DAM
(MAP 7)
LEECH LAKE RIVER
MUD L
FEDERAL DAM
GRAND RAPIDS
MISS RIV
POKEGAMA LAKE
LEECH LAKE
SOO LINE
N P
HUBBARD
WALKER
CASS
PINE
WHITEFISH LAKE
PINE RIVER
PINE RIVER RESERVOIR DAM
(MAP 10)
AITKIN
RIVER
McGREGOR
CROW WING
MISSISSIPPI
AITKIN
GULL
GULL
LONG L
GULL LAKE RESERVOIR DAM
(MAP 11)
BRAINERD
LEGEND
WATERSHED



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Groundwater

Above St. Paul, the Mississippi River region contains many lakes, most of which are water table lakes hydraulically connected to aquifers. Nearby wells can induce water to move from the lakes or streams, thus increasing well yields, particularly in sandy counties like Anoka, Isanti, and Sherburne. However, the overall effect of wells on water surfaces in adjoining lakes or streams is insignificant in the upper basin headwaters lakes area.

Sand and gravel deposits contain the largest quantities of water within the basin. Wells with potentially high yields of more than 2,000 gallons per minute are located in the north and west part of the basin where sand and gravel deposits (up to 200 feet thick) are adjacent to watercourses. In general, groundwater quality is less than 300 mg/l (milligrams per liter) total dissolved solids. The groundwater is hard and excessively high in iron.

Groundwater development is not high at the present time, but is increasing. Most of the groundwater use is centered in the sand plain areas where irrigation is the major use. The permeable and extensive aquifer units and the areas of natural surface storage can yield large quantities of water for municipal, agricultural, and industrial uses.

Geology and Soils

The controlled headwaters lakes of the Mississippi River are located in north central Minnesota. The drainage basins of these lakes are located principally in Aitkin, Beltrami, Cass, Crow Wing, Hubbard, and Itasca Counties.

The upper three lakes - Winnibigoshish, Leech, and Pokegama - lie in a region of geologically young, gray, glacial drifts from the Keewatin Center which, in the Grand Rapids area, become a thin veneer over a rugged moraine of Patrician or young red drift. Sandy, Pine River, and Gull Lakes lie in the red drift region. The gray drift is generally more clayey and less stony than the red drift. The drifts vary in thickness from 300 to 400 feet at the head of the Mississippi River to about 200 feet near Gull Lake.

Cass County, which contains three of the controlled lakes (Winnibigoshish, Leech, and Gull), comprises 1,998 square miles of gently rolling upland surface and numerous lakes. This topography is the result of deposition of glacial drift during the Wisconsin Age. Three general types of deposition are found in Cass County. In the north, along the south shore of Lake Winnibigoshish, is a sandy outwash plain. South of this outwash, in the vicinity of Leech Lake, is a substantial zone of till plain. The southwest portion of the county, from Leech Lake to northern Gull Lake, is part of the St. Croix moraine system.

At least 16 distinct types of soil are recorded in Cass County. The outwash of the northern part of the county has developed a light-colored, loamy sand with low inherent agricultural fertility. The soils in the remainder of the county are mixtures of sand, clay, and loam of fair to good fertility. Organic peat soils occur in numerous low-lying areas throughout the county. These soils have good fertility potential but present problems in physical structure and water holding capability.

Aitkin County, in which Sandy Lake is located, is predominantly till plain with a large outwash area to the northeast characterized by surface deposits of sand and gravel. The soil of the till plain area is brown and slightly acidic, with pebbles and boulders of granite and gneiss.

Crow Wing County, in which Pine River Lake (12 lakes) is located, consists primarily of glacial outwash, with considerable moraine along the eastern border and till plain along the southern margin. Pine River Lake is located on outwash soils predominated by sand and clay with fair to poor fertility.

Itasca County, in which Pokegama Lake is located, is characterized by surface features resulting from the Wisconsin glaciation over 10,000 years ago. The soils are diverse. Loamy sands characterize the east central and west central portions of the county. Silty lake sediments occur in several townships. Erosion-prone sand and peat deposits of low fertility occur in the southeastern part of the county, and a belt of reddish clay loam extends from the southwest to the northeast.

Veins of gravel and sand are located through the headwaters region, especially in the gray drift areas. These veins permit free interchange of water between the headwaters lakes and the underground water table. Sand and gravel deposits are found extensively in Cass, Crow Wing, and Itasca Counties as well as in and around Minneapolis-St. Paul at the southern extreme of the study area.

Mining

The Mississippi River basin contains two iron ore mining ranges, the Mesabi and Cuyuna. In Itasca County, the Mesabi Iron Range extends northeast to southwest across the prairie and the Mississippi River, passing through and terminating several miles southwest of Grand Rapids. The Cuyuna Iron Range runs parallel to and south of the Mississippi River in Crow Wing County.

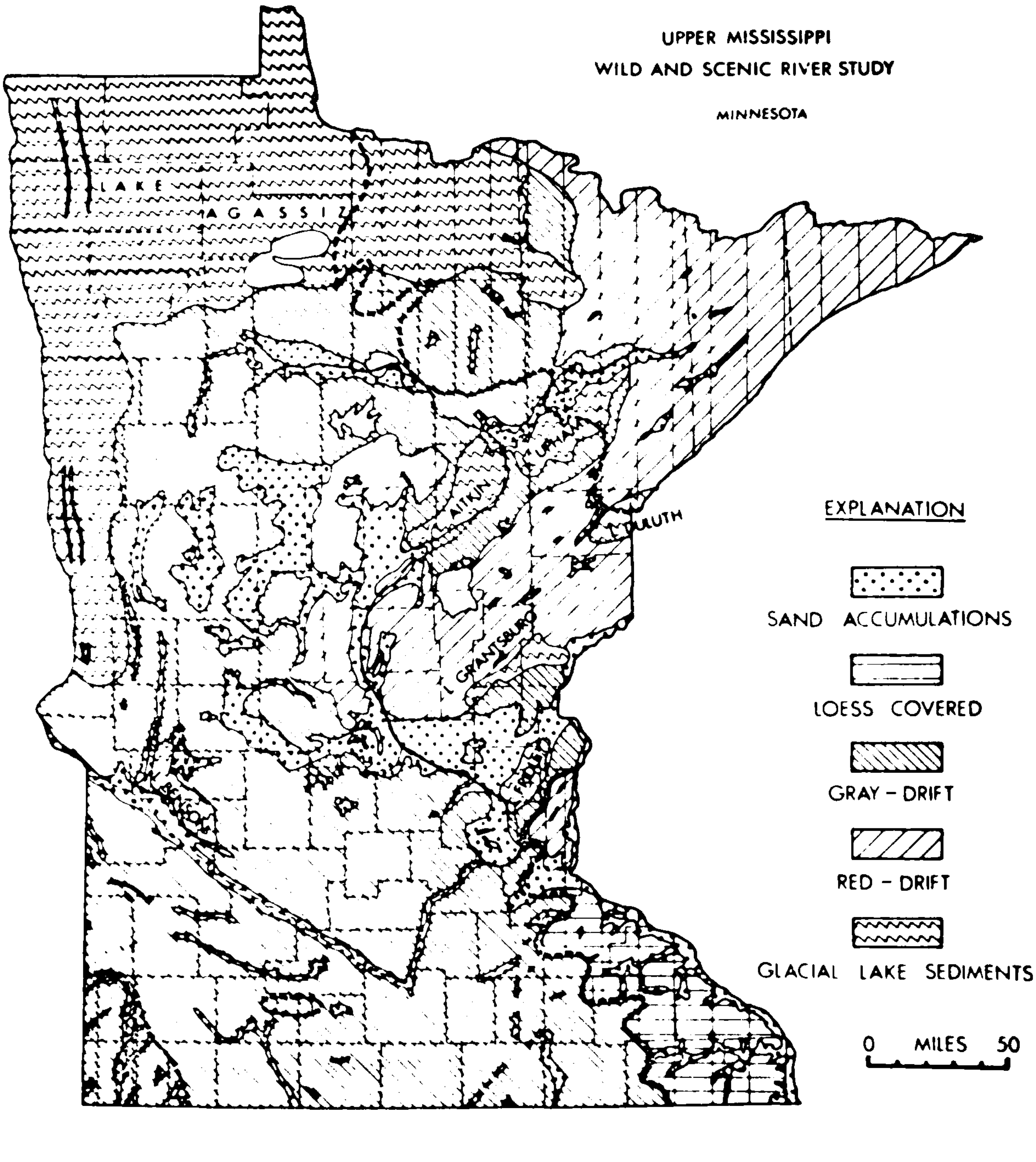
Iron ore reserves in the Mesabi range contain four major types: hematite, nonmagnetic taconite, magnetic taconite, and semitaconite. The Cuyuna range has large reserves of nonmagnetic, low-grade ores.

The locations of these two ranges with respect to the major mineral areas and surficial geology are determined from the following two figures.

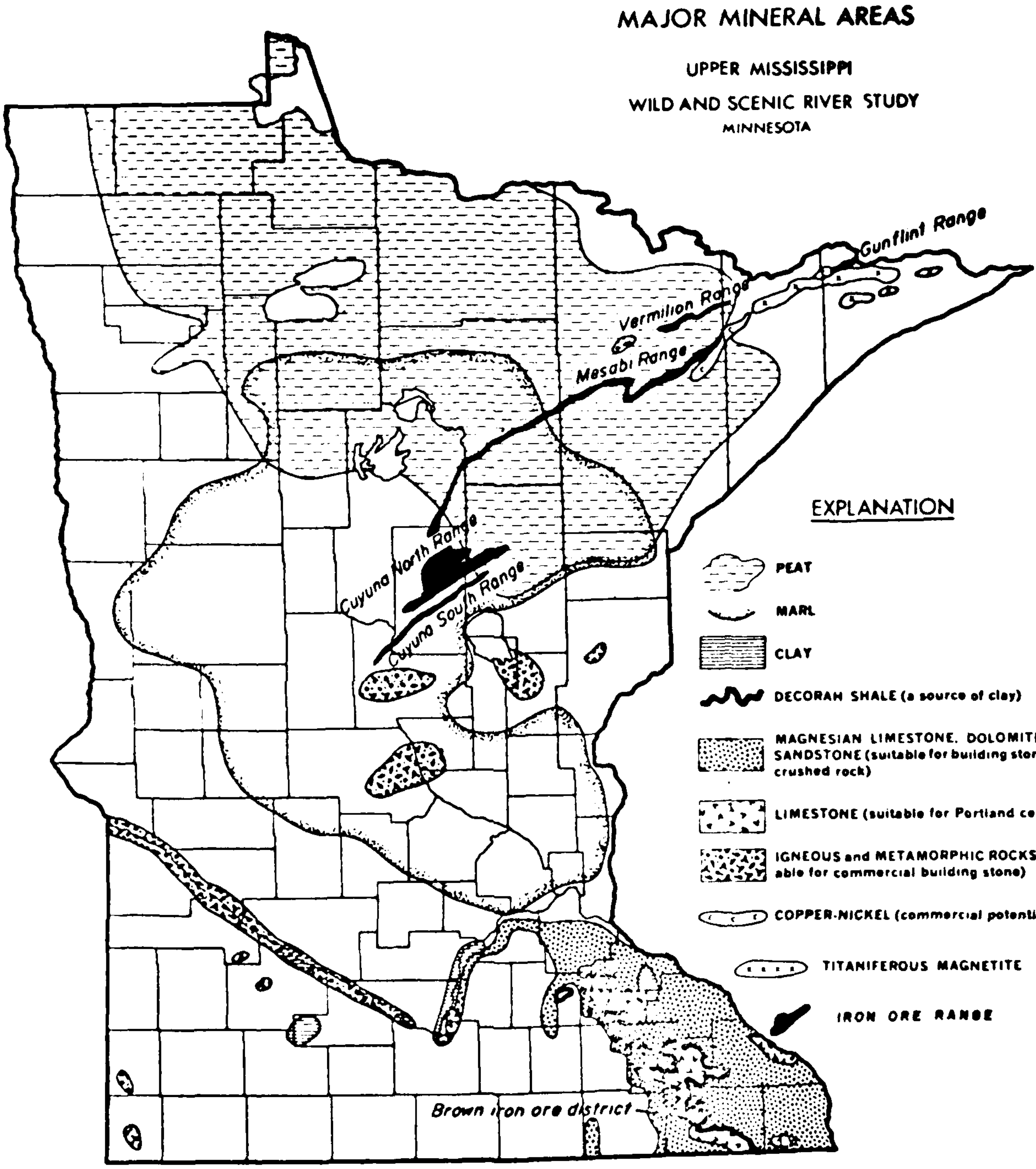
SURFICIAL GEOLOGY

UPPER MISSISSIPPI
WILD AND SCENIC RIVER STUDY

MINNESOTA



SOURCE Minnesota Geological Survey



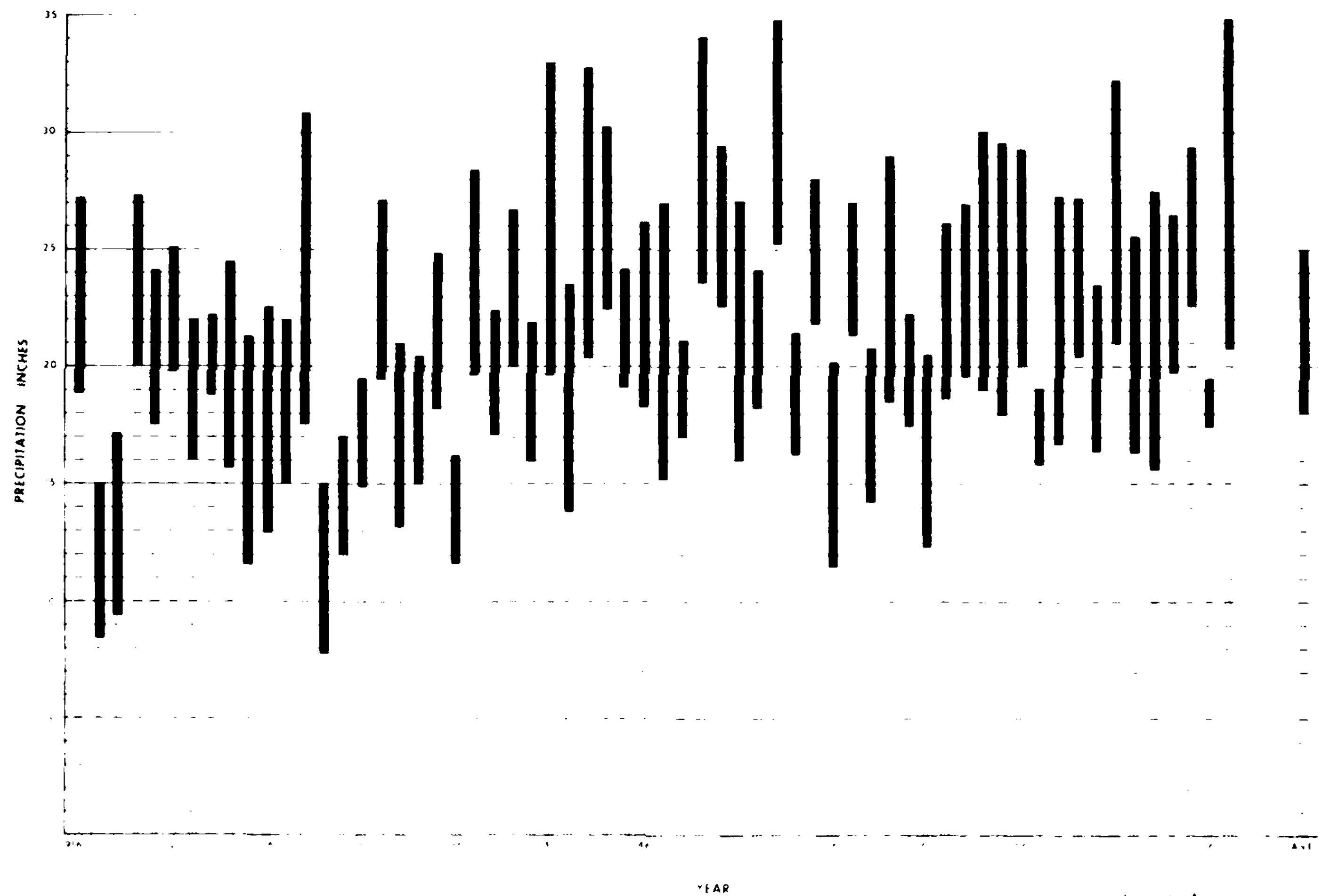
SOURCE Minnesota Geological Survey

Climate

The headwaters lakes area has warm, short summers and cold winters. At the northern end of the headwaters region, temperatures average about 5° F in January and about 65° F in the summer. In the southern portion of the area, temperatures are typically about 5° F warmer. Great extremes can occur and temperatures below -50° F and above 100° F have been recorded.

The growing season, between the last killing frost in the spring and the first killing frost in late summer or early fall, varies from about 143 days in Aitkin and Itasca Counties to 148 days in Crow Wing County. Other portions of the region have growing seasons of intermediate length.

The annual precipitation varies from 17 to 38 inches and averages 28 inches at the eastern end of the Sandy Lake watershed. At the western edge of the headwaters region, precipitation varies from 15 to 34 inches yearly, with an average of 22 inches. The evapotranspiration rate for the region is about 20 to 22 inches per year. The western edge of the region tends to have about half as much average annual runoff as the eastern edge of the region. Annual snowfall in the region is typically 43 to 50 inches. Annual precipitation at Grand Rapids is typical for the headwaters area and is shown on the following figure.



PRECIPITATION AT GRAND RAPIDS

1916 - 1977

Vegetation

The Mississippi River Headwaters watershed lies within the Minnesota section of the hemlock-white pine-northern hardwoods region of the deciduous forest in eastern North America. No hemlocks, however, occur in the study area. Climax communities vary considerably in the coniferous-hardwoods region. Sugar maple and basswood dominate the southern portion; white spruce, balsam fir, and paper birch dominate the northeastern reaches; and intermediate communities occupy intervening areas. Pine subclimaxes are common throughout the region. Pines often occupy sites which have light-textured soils, while hardwoods prefer the heavier soils. Oaks and aspen form successional communities on upland sites while elms and ash form communities on lowlying areas. Lowland conifers occupy wet areas having organic soils.

Forest communities dominate the shoreline vegetation of the six headwaters lakes while lesser amounts of bog, marsh, and grassy areas are present.

Fish

The bulk of the sport fish taken from the six lake areas are walleye and northern pike. All six lake areas have excellent walleye spawning areas and a better than average abundance of walleyes, according to recent surveys on all lakes except Pokegama Lake. Surveys also indicate that satisfactory to good northern pike populations are found in Winnibigoshish, Pokegama, and Leech Lakes. These lakes have good spawning conditions for "northerns" but the three southern lake areas (Pine River, Gull, and Sandy Lakes) apparently do not have northern pike in abundance. There is established muskie fishing in the six headwaters lakes, predominantly in Leech and Winnibigoshish Lakes.

Smaller species of fish play an important role in the total ecological picture of the lakes. About 30 such species have been identified in the lakes, constituting important forage for the game species and considerable sporting opportunities.

Mammals

Big game in the forested portions of the headwaters area consist of white-tailed deer, black bear, and moose. The timber wolf is also found in the region.

Small game available to hunters and trappers include mink, muskrat, and beaver which are harvested for their pelts. These animal populations vary, depending on water levels and trapping interests. Otters, weasels, muskrat, mink, and raccoon are found in the Mississippi bottomlands. In addition, bobcats, badgers, fox, rabbits, and squirrels are present in the headwaters region.

Birds

Many migratory birds winter south of the headwaters area but breed north of the area. Migratory birds which reach the southern limits of their breeding ranges within the headwaters region include the horned grebe, common goldeneye, bufflehead, common and red-breasted mergansers, goshawk and merlin(pigeon hawk), yellow rail, gray jay, red-breasted nuthatch, hermit and Swainsons thrushes, several warblers (Tennessee, magnolia, bay-breasted, palm, Connecticut, mourning, Canada, and northern waterthrush), evening grosbeak, and white-throated sparrow. Although northern species often retreat as people move into the area, some of these species may be encouraged by human activity. One former summer resident, the peregrine falcon, is now seen only occasionally as a transient. Its elimination as a breeding species in the central and eastern United States is probably largely the result of exposure to organochlorine compounds.

Several dominant northern birds reach their southern limits in this region. These include the spruce, ruffed, and sharp-tailed grouse; great gray owl; raven; boreal chickadee; and white-winged crossbill.

A large number of prairie birds, including many ducks, reach their eastern limits in this area. Among the prairie species that breed as far east as the headwaters region are the eared grebe, Canada goose, pintail, green-winged teal, American widgeon (baldpate), lesser scaup, ruddy duck, Wilsons phalarope, Foresters tern, common tern, western kingbird, sharp-tailed sparrow, and lark sparrow. The giant Canada goose once nested in this area.

Most of the shorebirds of the headwaters region are transients and some of them, such as the golden plovers, Bairds and western sandpipers, and the Hudsonian and marbled godwits, reach the eastern limits of their migration routes here. Others, such as the least and semipalmated sandpipers, though they range to the east coast, are more commonly seen in the prairie than in the headwaters region.

Some headwaters birds are basically eastern species that reach the western limits of their probable breeding ranges in this area. Among these are the wood duck and three warblers, the parula, black-throated blue, and Canada.

Other species which migrate this far north to reach the northern limit of their breeding range include the green heron, black-crowned night heron, least bittern, turkey vulture, woodcock, screech owl, brown thrasher, wood thrush, yellow-throated vireo, orchard oriole, scarlet tanager, indigo bunting, and field sparrow. The cardinal also reaches its northern limit here.

The great blue heron, the common loon, and the bald eagle are other migrant species found in the Mississippi River Headwaters area. In the Chippewa National Forest, the U.S. Forest Service has a continuing study on the bald eagle.

Reptiles and Amphibians

In Minnesota, reptiles and amphibians are generally limited in distribution by the cold. Several Minnesota species, however, are among the few cold-blooded terrestrial vertebrates that live as far north as Hudson Bay. Among these are the common garter snake, American toad, swamp chorus frog, leopard frog, and wood frog. Other species, such as the snapping and painted turtles, barely range into southern Canada. Some species are essentially eastern in distribution, such as the green frog and red-backed salamander, and are likely to be found only in the Big Sandy basin and perhaps in the eastern part of the Upper Mississippi River basin. The newt and blue-spotted salamander range west through the headwaters region to the forest edge. The tiger salamander is not found much farther northeast than the headwaters region. The bull, eastern hognosed, and plains garter snakes as well as the spiny, soft-shelled, and map turtles reach their northern limits within the headwaters region.

Endangered Species

There are no known endangered species in the study area. However, the Arctic and American peregrine falcons are endangered species that may still visit the Mississippi River Headwaters area during migration. The gray wolf and the bald eagle are present but are not endangered in the headwaters area. The Federal list of endangered and threatened species designates both species as threatened in Minnesota.

HUMAN RESOURCES

Population Figures

The population of the six-county study area was 136,038 in 1970, representing an average of 12.5 persons per square mile, compared to 45 persons per square mile for the entire State of Minnesota. The Upper Mississippi River Headwaters lakes and watersheds are within Aitkin, Beltrami, Cass, Crow Wing, Hubbard, and Itasca Counties in north central Minnesota. The major cities in these counties and their 1970 populations are Brainerd (11,667), Bemidji (11,490), Grand Rapids (7,247), Park Rapids (2,772), Aitkin (1,553), Cass Lake (1,317), and Walker (1,065). Pertinent data for the headwaters lakes counties are given in the following table.

Pertinent data for the Mississippi River Headwaters Lakes counties

County	Lake	Watershed	Area (square miles)	Population 1890	Population 1970	Density, persons per square mile 1890	Density, persons per square mile 1970	Percent rural population (19[illegible])	[illegible]
Aitkin	Sandy	Sandy	1,831	2,462	11,403	1.3	6.2	100	[illegible]
Beltrami	None	Winnibigoshish	2,507	312	26,373	0.1	10.5	[illegible]	[illegible]
Cass	Leech, Gull, Winnibigoshish	Pine River, Gull, Leech, Pokegama, Winnibigoshish	1,998	1,247	17,323	0.6	8.6	[illegible]	[illegible]
Crow Wing	Pine River	Pine River, Gull	995	8,852	34,826	8.9	35.0	66	[illegible]
Hubbard	None	Leech, Winnibigoshish	932	1,412	10,583	1.5	11.3	[illegible]	[illegible]
Itasca	Winnibigoshish, Pokegama	Winnibigoshish, Pokegama	2,633	743	35,530	0.3	13.4	80	[illegible]
Total			10,896	15,028	136,038				

SOURCE: Minnesota State Board of Health, "Minnesota Vital Statistics," Minneapolis, Minnesota, [illegible].

Social Characteristics

The headwaters lakes area is predominantly rural. Not only are the towns small, but they are usually farther apart than in southern Minnesota. Typically, the farms are small and often only marginally productive. The area has a natural beauty that appeals to outdoor enthusiasts, fishermen, hunters, snowmobilers, and skiers.

Most of the residents of this area, though rural, are classified as rural nonfarm because they do not reside on farms but live in small towns of less than 2,500 persons or in homes in the country. Each of the counties has more than twice the percentage of rural nonfarm residents as the State as a whole, as shown in the following table.

Residence distribution of headwaters area population (1970)

Area	Rural farm (percent)	Rural nonfarm (percent)	Urban (percent)
Minnesota	12.8	20.8	66.4
Aitkin County	29.3	70.7	0.0
Beltrami County	30.1	46.1	23.8
Cass County	20.6	79.4	0.0
Crow Wing County	14.6	51.9	33.5
Hubbard County	24.0	49.8	26.2
Itasca County	8.6	71.0	10.4

SOURCE: U.S. Department of Commerce, Bureau of the Census, Census of the Population, 1970.

The population growth of many of these counties peaked around 1940 and has since been leveling off. Aitkin County shows a sharp population drop and Cass and Hubbard Counties exhibit smaller declines as shown in the following table. Beltrami, Crow Wing, and Itasca Counties have seen some growth in population since 1940, but at a much lower rate than the State as a whole.

[illegible]

Area	Year					Percent change
	1930	1940	1950	1960	1970	1940-70
Minnesota	2,563,953	2,792,300	2,982,483	3,413,864	3,804,971	+36.2
Aitkin County	15,009	17,865	14,327	12,162	11,403	-36.2
Beltrami County	20,707	26,107	24,962	23,425	26,373	+1.0
Cass County	15,591	20,646	19,468	16,720	17,323	-16.1
Crow Wing County	25,627	30,226	30,875	32,134	34,826	+15.2
Hubbard County	9,596	11,085	11,085	9,962	10,583	-4.5
Itasca County	27,224	32,996	33,321	38,006	35,530	+7.7

SOURCE: U.S. Department of Commerce, Bureau of the Census, Census of the Population, 1970.

The non-SMSA portion of the Water Resources Subregion 7, Mississippi River Headwaters projection for 1980 is $3,400 per capita income. This area excludes the metropolitan counties of Anoka, Hennepin, Ramsey, Washington, and Dakota. Future projections including 1980 are listed in the following table.

Per capita income projections, non-SMSA portion of the Mississippi River Headwaters Lakes area

Year	Per capita income (1)
1980	$3,400
1985	4,000
1990	4,600
2000	6,300
2020	10,600

(1) All figures in 1967 dollars.

The per capita income in Minnesota in 1970 was $3,052. Of the six area counties, Crow Wing County has the highest per capita income of $2,383, although it is approximately $700 below the State average. Hubbard County has the lowest per capita income ($2,018), which is only 66 percent of the State average. Other selected income and education characteristics are shown in the following table.

Selected income and education characteristics, 1970

Area	Income per capita	Families with incomes below poverty level (percent)	Families with incomes of $15,000 or more (percent)	Median years education (1)
Minnesota	$3,052	8.2	20.3	12.2
Aitkin County	2,094	18.3	6.4	9.8
Beltrami County	2,193	17.3	10.7	12.0
Cass County	2,054	21.4	7.8	10.7
Crow Wing County	2,383	11.6	10.2	11.5
Hubbard County	2,018	20.7	8.1	12.0
Itasca County	2,346	12.7	7.7	11.7

(1) Persons 24 years of age or older.

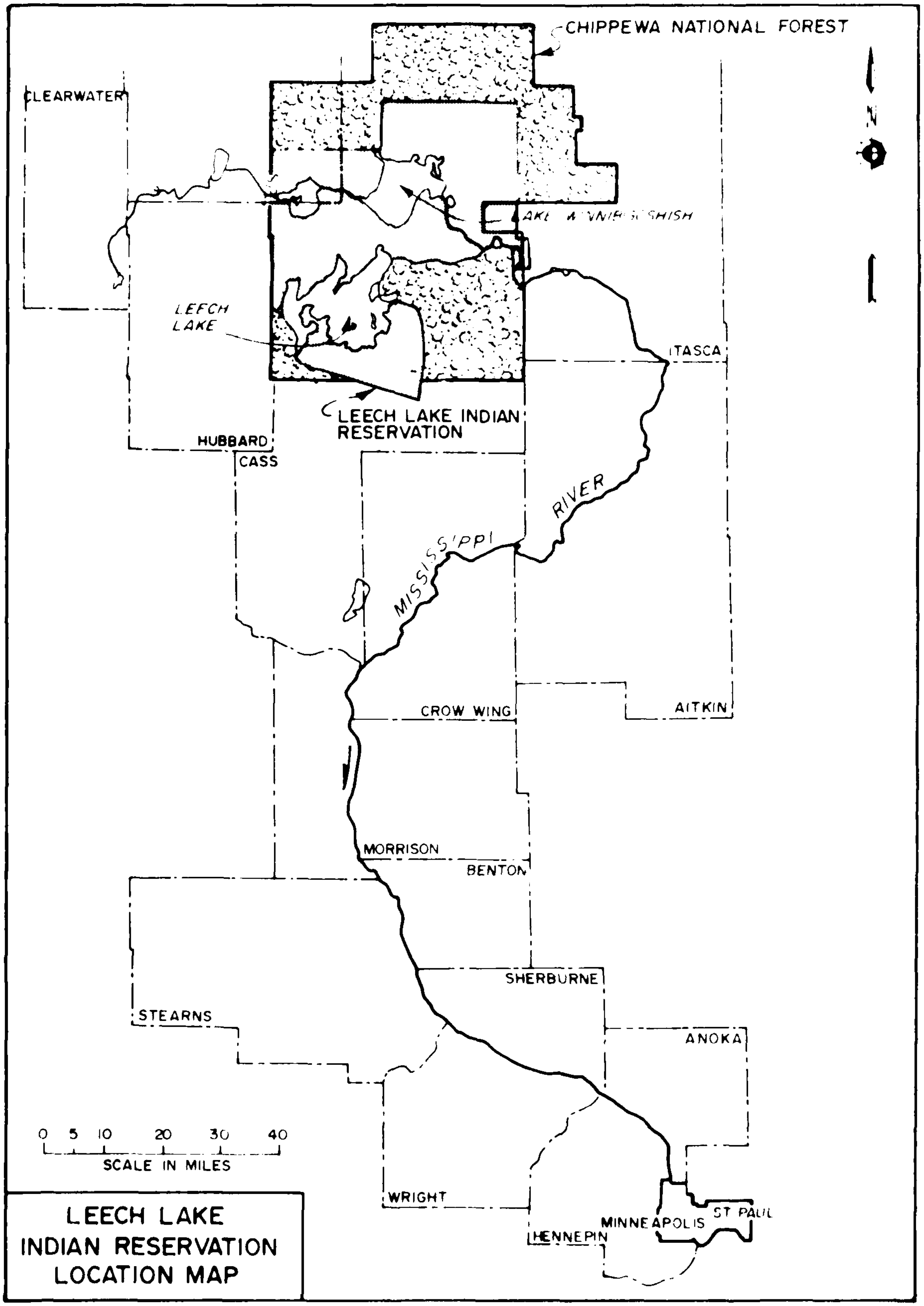
SOURCE: U.S. Department of Commerce, Bureau of the Census, Census of the Population, 1970.

The poverty income level referred to on the previous table is defined as a range of incomes depending on sex, head of family, age, size of family, and whether the family is farm or nonfarm. The average national poverty threshold for a nonfarm family of four, headed by a man, is $3,745.

Hubbard County families in the Mississippi River Headwaters area maintain the largest percentage (20.7) below the nonfarm family poverty level, while Crow Wing County accounts for the lowest percentage (11.6) below the nonfarm family poverty level.

The median years of education for adults 25 years [illegible] in the six area counties is slightly below the state median. [illegible] County has the lowest median years of education ([illegible]) and Beltrami and Hubbard Counties have the highest (12.0).

The Mississippi River Headwaters area contains all or part of three Chippewa Indian Reservations: Leech Lake, White Earth, and Mille Lacs. Only the Leech Lake Indian Reservation is affected by the proposed study. The following map shows the location of the Leech Lake Indian Reservation. (White Earth Reservation is west and almost entirely outside the headwaters basin and Mille Lacs Reservation consists of only scattered tracts; therefore, neither is shown on the map.)


CHIPPEWA NATIONAL FOREST
CLEARWATER
LEECH LAKE
ITASCA
LEECH LAKE INDIAN RESERVATION
HUBBARD
CASS
MISSISSIPPI RIVER
CROW WING
AITKIN
MORRISON
BENTON
SHERBURNE
STEARNS
ANOKA
0 5 10 20 30 40
SCALE IN MILES
WRIGHT
HENNEPIN
MINNEAPOLIS
ST PAUL
LEECH LAKE
INDIAN RESERVATION
LOCATION MAP

Once one of the largest Indian Nations north of Mexico, the Chippewa, also known as the Ojibway, controlled lands from the shores of Lakes Huron and Superior westward to central North Dakota. The Chippewa were nomadic timber people, traveling in small bands and engaging primarily in hunting and fishing, though some agriculture was also practiced. The Chippewa have officially been at peace with the United States Government since 1815 and are currently found in the northern United States and parts of Canada.

The Leech Lake Indian Reservation is a distinctive component of contemporary society in the Mississippi River Headwaters area. The reservation was established in 1854 by treaty with the United States Government and originally included almost 1 million acres. By congressional acts and Executive orders, the reservation was reduced in size so that its present boundary encompasses about 589,000 acres. Land around two of the headwaters lakes (Winnibigoshish and Leech Lakes) is included in the reservation. The operation of the headwaters lakes has multiple effects on the Chippewa Indian community living on and adjacent to the reservation.

The Leech Lake Indians have an interest in the protection of prehistoric and historic Indian archeological sites (especially burial grounds around the headwaters lakes) and in the development and maintenance of recreation facilities as well as wild rice production and commercial fishing. A number of businesses on the reservation are Indian owned, such as a marina and campground, bowling alley, lounge and laundromat, grocery store, service station, cafe, wild rice paddy, logging operation, and other retail and service enterprises.

The following two tables compare the population and income of Chippewa Indian tribes in Minnesota with county and Leech Lake Reservation per capita incomes.

Statistical data - Minnesota's Chippewa Indian Reservations
(Compiled from League of Women Voters' Report)

Reservation	Total acres	Percent of original	Population 1960	Population 1970	Percent change	Income per capita
Grand Portage	44,752	82	325	212	-34.8	$1,067
Fond du Lac	21,367	51	850	744	-12.5	851
Leech Lake	589,000	5	2,750	2,795	+1.6	559
Mille Lacs	3,619	-	800	827	+3.4	847
Nett Lake	41,784	41	600	675	+12.5	973
White Earth	56,116	8	2,550	2,659	+4.3	831
Red Lake	564,426	100	3,200	2,759	-13.8	1,200

Leech Lake Indians - per capita income (1968) and taxable land

Item	County Beltrami	County Cass
Indians in population (percent)	11	8
Per capita income, entire county (1)	$1,839	$1,634
Amount of taxable county land (percent)	29	32

(1) Leech Lake Reservation per capita income, $559 in comparison.

Historical and Archeological Resources

Prehistoric inhabitants of the Mississippi River Headwaters area left considerable remains of their culture along the area lakes and river shorelines. The six Mississippi River Headwaters Lakes have a significant number of cultural or historic sites that were first identified in a preliminary 1973 inventory by Bemidji State University and in more current (1977-78) detailed surveys by the University of Minnesota. The total number of sites identified in the two surveys varies because of an inability to correlate some of the sites reported during the 1973 inventory and later surveys. The number of sites identified for each of the six lakes in these two studies is as follows:

Lake	1973 inventory	1977-78 survey	Total identified to date
Winnibigoshish	14	27	30
Leech	32	79	89-90
Pokegama	15	37	44-46
Sandy	9	35	37-39
Pine River	8	23	26-27
Gull	5	18	20-21
Total	83	219	246-253

The cultural resources investigations at the reconnaissance level are completed on all Corps-owned lands and flowage easements at the six primary headwaters reservoirs. Twelve ancillary lakes which are part of the reservoir systems at Gull and Pine River Lakes still require surveys. As indicated above, 219 prehistoric and historic sites were identified during the investigations completed to date, which involved a surface examination of the shoreline and eroding banks and, in some cases, limited testing.

These sites revealed a human occupation span of at least 7,000 years in the headwaters region. The first known inhabitants were people of the Eastern Archaic cultural tradition dated at about 5000 B.C. Eight prehistoric American Indian cultural traditions and three historic tribes (the Yanktonai and Sisseton Dakota and the Ojibwa) are represented. The headwaters region was also an important center for the French, British, and American fur trade and for the logging industry in the 1880's. Homesteads were not generally established in the area until the end of the logging era, about 1910.

Approximately 97 of the 219 sites are subject to erosion from the lakes and require protection or recovery to prevent the loss of valuable historic and cultural data. The erosion is the result of high water levels, water level fluctuations, and wave action in the pool areas. The breakdown of sites currently being damaged by erosion is as follows:

Reservoir	Number of sites	Sites eroding
Winnibigoshish	27	7
Leech	79	31
Pokegama	37	28
Big Sandy	35	14
Pine (Whitefish, Upper Whitefish, and Cross Lakes)	23	11
Gull and Upper Gull Lakes	18	6
	219	97

Of the 97 sites subject to erosion at this time, 80 are in imminent danger of destruction due to severe erosion. Many of these sites have unique features of great scientific research or interpretive value. Among these are unusually northern occurrences of Onamia and Brainerd Ware pottery; one of the few Early Woodland sites in northern Minnesota; a small number of highly important multicomponent sites which may yield information on the transitions between various cultural traditions; early fur trading posts; logging camps; and burial mounds.

In addition, the headwaters lakes have seven properties and one district listed on the National Register of Historic Places: the Sherwood Forest Lodge Complex, Grand View Lodge, Chase Hotel, Winnie Resort, Winnie Dam, Gull Lake Mound Site, St. Columbia Mission, and the Gordon-Schaust Prehistoric Embankment District. It is expected that additional surveys will locate many times this number of significant sites in the headwaters region.

Detailed information on each site is contained in a separate report for each lake prepared by the University of Minnesota or private firms under contract with the St. Paul District, Corps of Engineers.

DEVELOPMENT AND ECONOMY

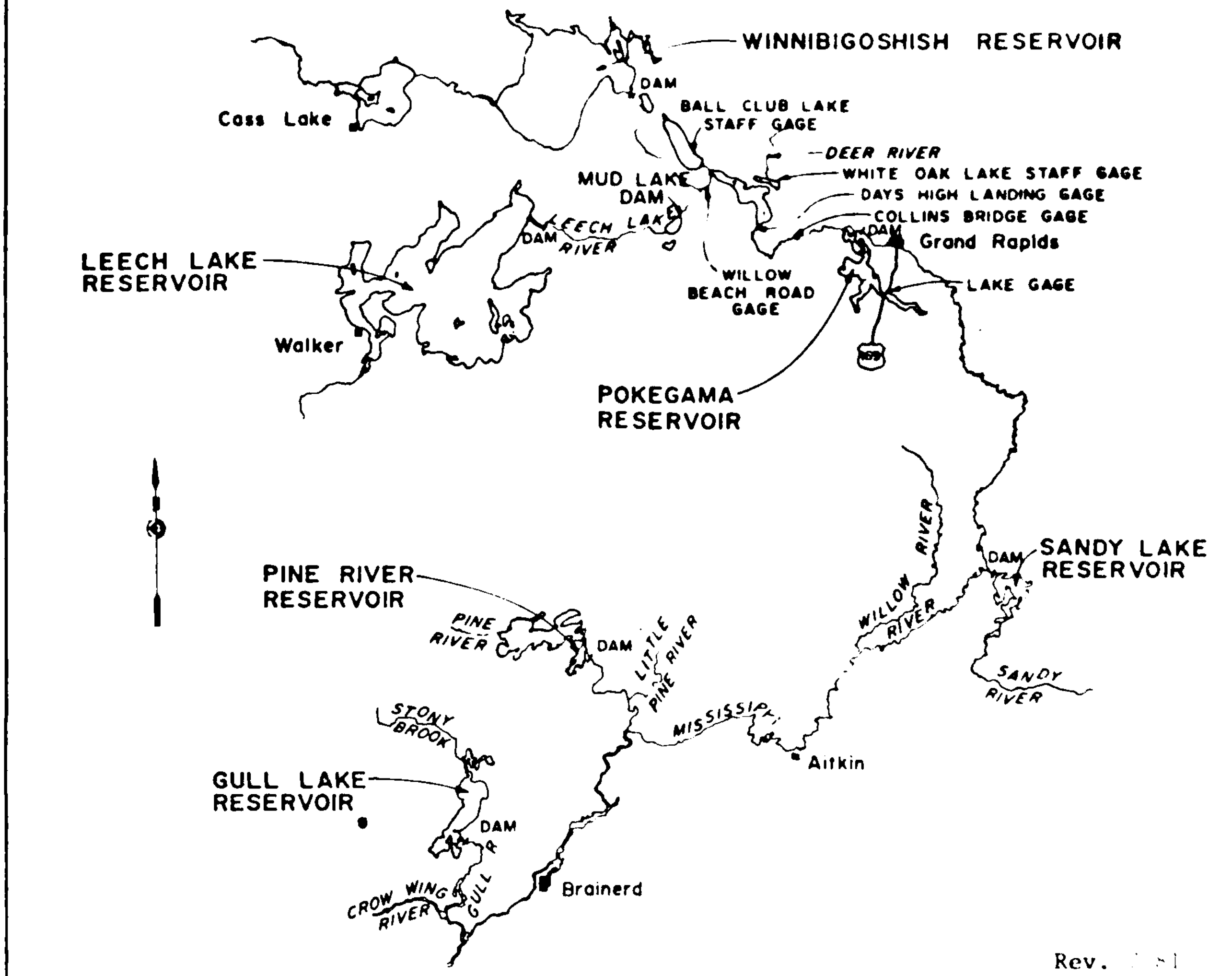
The Mississippi River Headwaters area first became inhabitable about 10,000 years ago after the retreat of the last glaciers. The area is rich in archeological remains of prehistoric and historic habitation with 214 known cultural and historic sites on the 6 controlled headwaters lakes shorelines. The sites are related to American Indian cultures, the fur trade, and the early logging industry.

The rise of large-scale logging in the 1890's provided the impetus for settlement and development of the region. By 1900 the largest logging camps in the area were in Itasca and Beltrami Counties. Early in the 20th century, pulpwood replaced saw timber as the major forest product and farms gradually replaced forests. Hundreds of miles of drainage ditches were constructed in an effort to reclaim peat lands and marshy areas. Some of these efforts were successful. However, some settlers found their land unfit for farming; consequently, farms were abandoned and much land became tax delinquent. The drainage ditches did not reclaim the land but instead created fire hazards and harmed natural resources. Eventually the State assumed the ditch bond obligations originally instigated at lower levels of government.

The Corps of Engineers constructed six water control dams on lakes in the headwaters area of the Mississippi River between 1881 and 1913, primarily to benefit river navigation with incidental benefits for logging. Most of the land bordering the lakes was originally owned by the Federal Government, and flowage easements were acquired on all other riparian lands. Much of the land owned in fee was later sold, although the Government reserved, and still retains, all flowage rights on lands required for full operation of the lakes. All homesites, resorts, and commercial establishments on the shore of these lakes have been developed on lands leased from the Government or on privately owned lands subject to Government rights.

The need for water release to aid navigation was greatly reduced by completion of a 9-foot navigation channel below Minneapolis in the 1930's. With the development of recreation as a business, recreation interests exerted constantly increasing pressure on the Government to stabilize water levels in the lakes. Both upstream and downstream interests became increasingly concerned about the flood control effects of headwaters lakes operation. Successive modifications of the operating regulations were made by which minimum levels were raised and storage capacity drastically reduced. The following table summarizes Mississippi River Headwaters Lakes elevations and other pertinent data.

GENERAL OPERATING DATA – MISSISSIPPI RIVER HEADWATERS RESERVOIRS



LAKE ELEVATIONS IN FEET – 1929 ADJ.

RESERVOIR	WINNI-BIGOSHISH	LEECH	POKEGAMA	SANDY	PINE	GULL
NORMAL SPRING STAGE (DATE)	1296.94 (3/1)	1293.20 (3/1)	1270.42 (3/5)	1214.31 (2/15)	1227.32 (2/15)	1192.75 (2/15)
DESIRABLE SUMMER RANGE	1298.94-1299.44	1294.50-1294.90	1273.17-1273.67	1216.06-1216.56	1229.07-1229.57	1193.75-1194.00
ORIGINAL OPERATING LIMITS	1288.94-1303.14	1292.20-1297.94	1268.92-1276.42	[illegible]-1218.31	1217.62-1234.82	1188.75-1194.75
CAPACITY, ORIGINAL OPERATING LIMITS, AC-FT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PRESENT OPERATING LIMITS	1294.94-1303.14	1292.70-1297.94	1270.42-1276.42	1214.31-1218.31	1225.32-1231.32	1192.75-1194.75
PRESENT ORDINARY OPERATING LIMITS	1296.94-1300.94	1293.20-1295.70	1270.42-1274.42	1214.31-1218.31	1226.32-1230.32	1192.75-1194.75
DESIRABLE OPERATING LIMITS	1296.94-1299.44	1293.20-1295.70	1271.42-1274.42	1214.31-1218.3	1227.32-1230.32	1192.75-1194.75
CAPACITY, PRESENT OPERATING LIMITS, AC-FT	[illegible]	[illegible]	[illegible]	37,600	79,900	26,000
FLOWAGE RIGHTS ACQUIRED TO ELEVATION OF	1306.94+	1301.70+	1280.42+	1222.31+	1238.82+	1198.75+
MAXIMUM ELEVATION EVER ATTAINED	1303.39	1297.88	1277.92	1224.82	1234.56	1195.05
NUMBER OF TIMES UPPER OPERATING LIMIT HAS BEEN EXCEEDED	2	0	18	18	0	8
NO TIMES FLOWAGE LIMITS HAVE BEEN EXCEEDED	0	0	0	1	0	0
MAXIMUM ELEVATION ATTAINED 1950	1303.17	1296.81	1277.39	1224.82	1231.41	1195.01
RESERVOIR IN OPERATION	1884	1884	1884	1895	1886	1912

[illegible] in northern Minnesota provide goods and services to persons living both within and outside the area. Farm products and manufactured goods are used locally and shipped out of the area. Services are rendered for tourists as well as permanent and summer residents.

Hundreds of lakes and numerous streams and rivers scattered among the timbered, rolling hills in the headwaters area provide magnificent scenery and some of the Nation's finest sporting grounds. More than 200 resorts abound in the headwaters area, serving over 1,500,000 tourists who annually contribute over $20 million to the region's economy.

The north central Minnesota counties form one of the major wild rice regions of the United States, with area production in excess of 2 million pounds annually. Minnesota's peat reserves are among the largest in the United States and are estimated at 5 billion tons (dry basis), which is about one-half of the national reserve. About one-tenth of the State's land area is peat bogs with most of this land in northern, north central (headwaters area), and northeastern counties.

Employment is increasing most rapidly in the finance, insurance, real estate, and service sectors of the Mississippi River Headwaters area and in the State of Minnesota. A 75-percent increase in the service sector for the headwaters area from 1950-1970 can be compared with a 164-percent increase for the entire State. Employment in agriculture decreased drastically from 12,266 employed in 1950 to 4,438 employed in 1970, or a 64-percent decrease in that category for the Mississippi River Headwaters area. In comparison, the State employment in agriculture also declined by 57 percent over the 20-year period. Wholesale and retail trade increased while transportation, communication, and utilities decreased in the headwaters area during this period. These and other employment changes shown in the following table indicate economic development for the 20-year period, 1950 to 1970.

[illegible] employment and employment changes by industry

[illegible]	Headwaters area (1) 1950	Percent of 1950 total	1960	Percent of 1960 total	1970	Percent of 1970 total	Percent change 1950–1970	Minnesota 1950	Percent of 1950 total	1960	Percent of 1960 total	1970	Percent of 1970 total	Percent change 1950–1970
[illegible]	[illegible]	[illegible]	[illegible]	16	4,438	11	-64	260,831	23	178,447	14	111,030	7	[illegible]
[illegible], com- [illegible], and [illegible]	[illegible]	[illegible]	[illegible]	7	2,632	6	-27	96,242	8	89,847	7	96,004	6	
[illegible] retail trade	[illegible]	[illegible]	[illegible]	18	9,005	22	+33	228,208	20	241,220	19	322,579	21	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	23	12,969	32	+75	200,139	17	263,702	21	529,337	35	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	12	5,162	13	-31	186,905	16	240,222	19	309,222	20	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,012	3	+86	37,326	3	50,349	4	67,779	[illegible]	[illegible]
[illegible] construction	[illegible]	[illegible]	[illegible]	[illegible]	2,793	7	-18	63,233	6	68,048	5	22,759	2	[illegible]
[illegible] reported	[illegible]	[illegible]	[illegible]	16	5,688	6	-13	73,175	7	106,436	11	54,437	[illegible]	[illegible]
[illegible]		[illegible]		100		100			100		100		100	

[illegible] Aitkin, Beltrami, Cass, Crow Wing, Hubbard, and Itasca.

[illegible] County" 1940-50, 1950-1960, U.S. Department of Commerce, 1965.
[illegible] Department of Commerce, Bureau of the Census, 1973.

[illegible] water-based recreation in the headwaters area is unknown. Approximately [illegible] [illegible] State of Minnesota at present, of which 60,000 are located in the Twin Cities [illegible]

Total agricultural employment in the headwaters area counties dropped from 5,453 in 1965 to 5,331 in 1969 and is projected to decrease to about 4,000 in the period from 1980 to 2000. Declining employment opportunities in agriculture have led to heavy rural out-migration. Although the urban centers of the region have experienced net in-migration, it has not been sufficient to offset rural out-migration. Regional population growth has been below the national average. Thus, while growth in population exceeded 30 percent in Minnesota and the United States between 1950 and 1970, the growth for the headwaters area was approximately 1.5 percent for the same period.

Agriculture is relatively more important in the headwaters region than in the Nation as a whole. The family farm is the dominant unit in Upper Midwest agriculture and hired labor is relatively unimportant. Thus, people are not "laid off" from agriculture, and unemployment rates in farm areas are relatively low. Underemployment, however, is a major problem. Many people on farms would like more work than can be productively undertaken on their land. As income levels of farmers often fall below those of persons engaged in nonfarm activities, some of the region's farmers have sought supplementary off-farm employment and income; however, such opportunities, especially in the sparsely populated headwaters counties, are not great. Relatively low income levels and limited employment opportunities have led large numbers of the region's farm population to move off the farm and seek employment elsewhere.

A severe problem prevalent throughout many parts of the region is seasonal unemployment. The area is characterized by heavy employment in the natural resource oriented industries. Since a major component of these industries is extraction or harvesting, outside work is demanded. During winter, severe weather conditions greatly curtail the amount of work that can be accomplished outside. During spring and fall, rain and melting snow create difficult transportation problems, especially in the forestry and agricultural industries.

A significant contributor to seasonal fluctuations in employment is the tourist industry. In areas where the tourist season lasts 4 or 5 months, the drop in off-season employment in the service and retail trade industries drastically affects the unemployment rates. This is especially true of the headwaters area where unemployment rates have fluctuated between 5.4 and 9.1 percent between 1965 and 1970. However, the increase in the popularity of skiing, snowmobiling, and other winter sports is tending to decrease seasonal variations of employment in this area.

SOCIAL ATTITUDES

A survey detailed in the Environmental Review of the Headwaters of the Mississippi Reservoir Projects (1973) considered social and attitudinal responses attributed to seasonal and permanent lakeshore residents, recreation area users, and businessmen and local government officials.

Resident perception of the factors influencing lake quality provided insights and additional documentation of environmental impacts not perceived by a nonresident population. A primary concern to these residents was the effect of water level changes within the lakes. Approximately three-quarters of the residents believed that the water level was satisfactory. Factors believed to be most important in determining water levels included flood control downriver, fish reproduction in the lakes, public water supply demands of the Twin Cities, navigation requirements on the Mississippi River, and control of lakeshore erosion.

Another aspect of potential environmental impact involves the effects of dams and recreation and camp areas on water quality. Of the representative residents questioned, 53 percent of the total believed that the lake they lived on was as clean or cleaner than most neighboring lakes.

[illegible] lists the concerns most [illegible] residents as being potential problems. Factors most frequently mentioned are algae growth, a decline in fish population, water pollution, a decline in hunting, and shoreline erosion.

Resident attitude of potential problems at the lakes(1)

Concerns	No problems	Minor problem	Major problem	Do not know	No response
	(percent)				
Too many tourists	79	16	3	1	1
Flooding	78	18	6	3	1
Excessive use of lake	76	19	5	-	1
Need for dredging	67	19	8	6	1
Overbuilding on shore	66	21	11	3	1
Excessive powerboats	62	24	13	-	1
Ice damage	60	30	5	4	1
Decline in hunting	41	22	8	29	1
Shoreland erosion	46	32	14	8	1
Water pollution	39	36	18	7	1
Decline in fishing	33	29	28	9	1
Algae growth	30	50	17	3	1

(1) Environmental Review of the Headwaters of the Mississippi Reservoir Projects, 1973: D-IX-32.

A majority of the residents believed that the Corps of Engineers administered recreation areas were well maintained and had no major negative effect on the lake. While 79 percent of the residents questioned in 1973 believed that the public recreation areas should be kept at their present size rather than expanded, response at public workshops held in conjunction with this study indicated a desire for increased recreation facilities.

Of the 235 recreation area users questioned by the Center for Environmental Studies at Bemidji State University, the greatest percentage (22 percent) were professional, technical and related workers. This group of users was followed by managers, officers, and proprietors (16 percent) and craftsmen, foremen, and kindred workers (15 percent). The smallest percentages of users were farmers, farm managers, and students (each 1 percent).

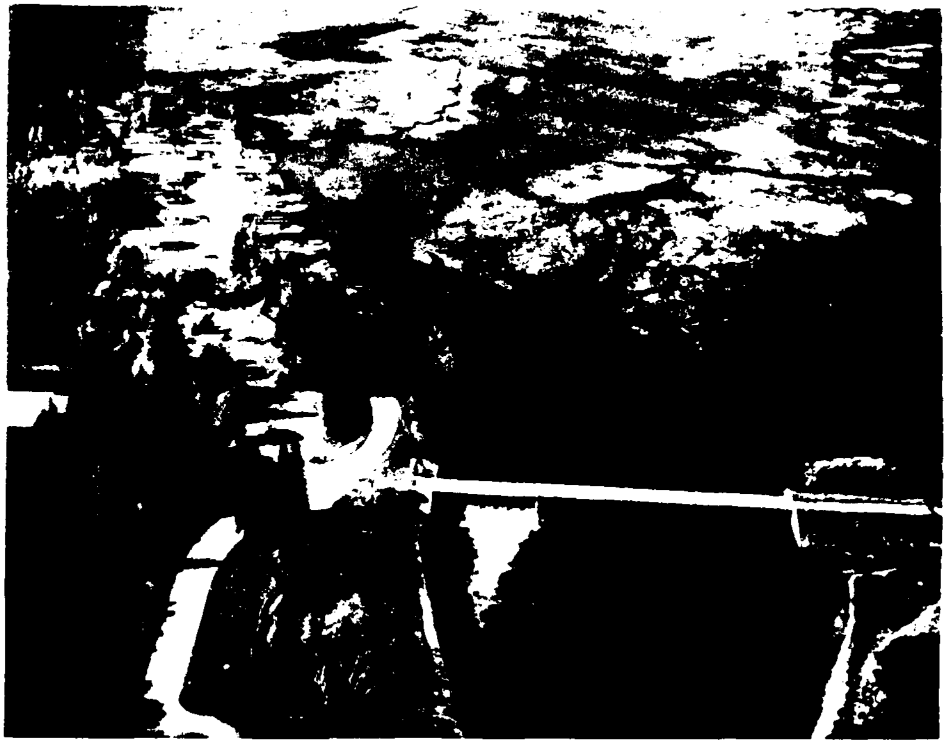
The most popular activities in order of importance are sightseeing, swimming, and hiking.[1] Activities having the greatest negative effect on the environment, according to respondents questioned by the Center for Environmental Studies, were pleasure boating, water-skiing, and motorbike riding.

The recreation industry in the headwaters area is a major economic consideration. Businessmen in communities near the lakes are the major beneficiaries of tourism. With regard to the economic and social life of these communities, businessmen and local government officials perceived differences only in those who were either lakeshore residents or campers. No clear distinction was made between vacationers at Corps of Engineers administered recreation areas and tourists who stayed elsewhere.

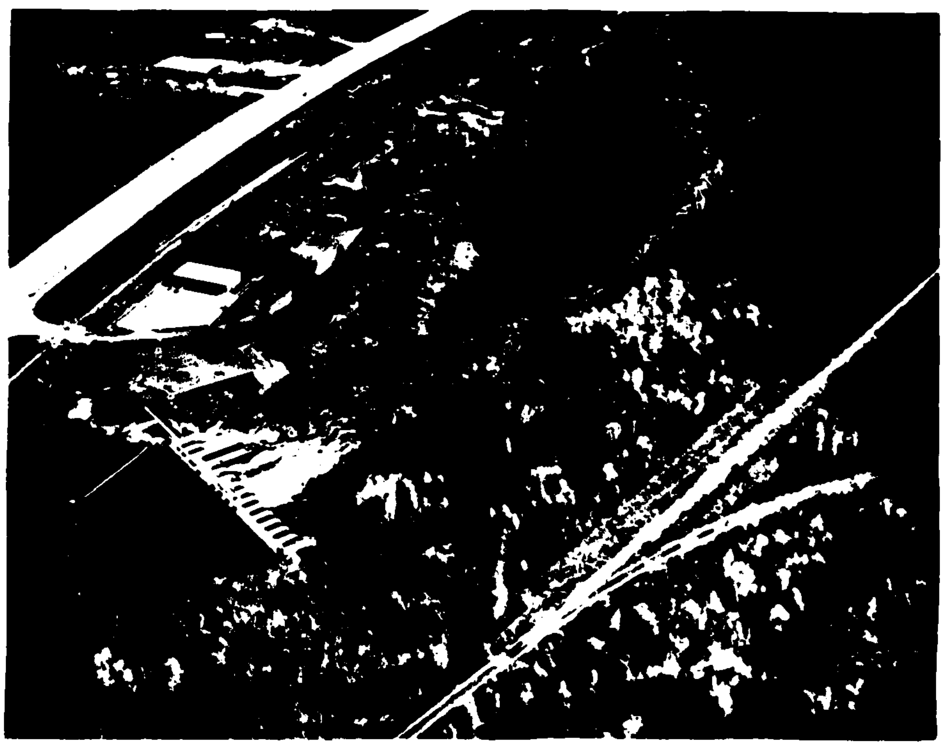
PROBLEMS AND NEEDS

The problems and needs considered in this report are those that relate to the operation of the six Mississippi River Headwaters Lakes. These problems were defined through review of the former reports, written requests by State and local interests, and contacts with local area representatives and the general public. The area covered is not restricted to the immediate area around the lakes, but includes consideration of significant effects of the headwaters lake releases along the Mississippi River down to and including the Minneapolis-St. Paul metropolitan area.

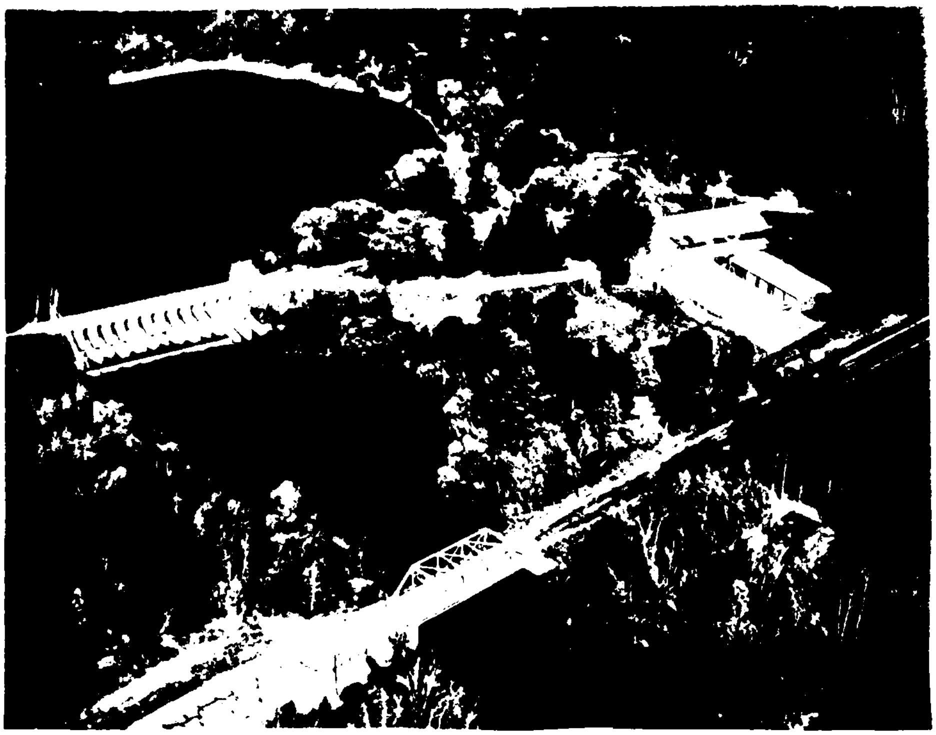
(1) Minnesota State Comprehensive Outdoor Recreation Plan - 1974, pages 5-17.



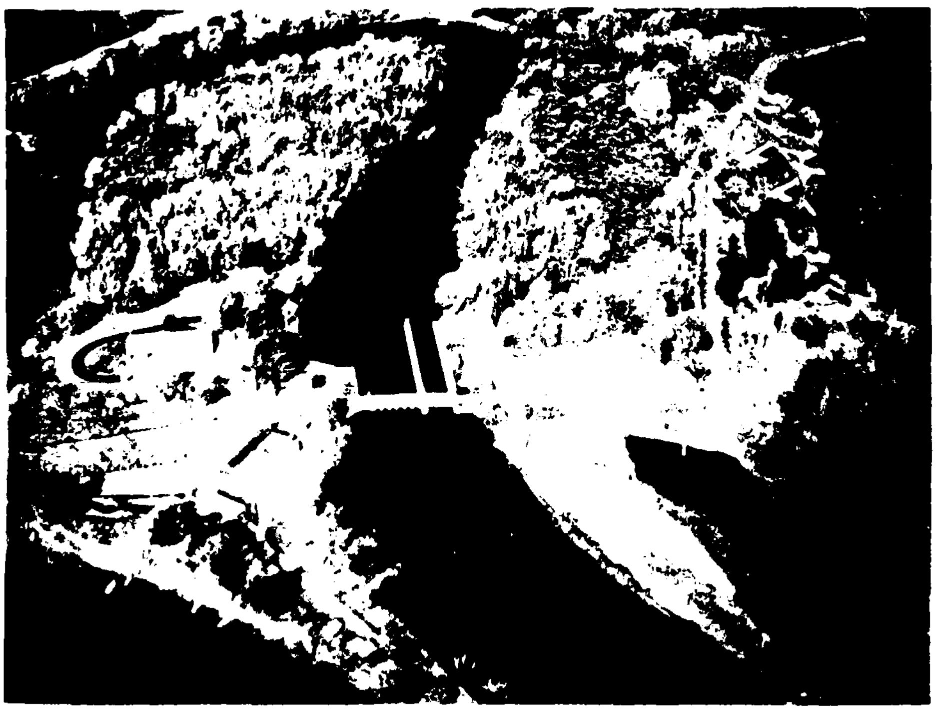
LEECH LAKE DAM



POKEGAMA LAKE DAM



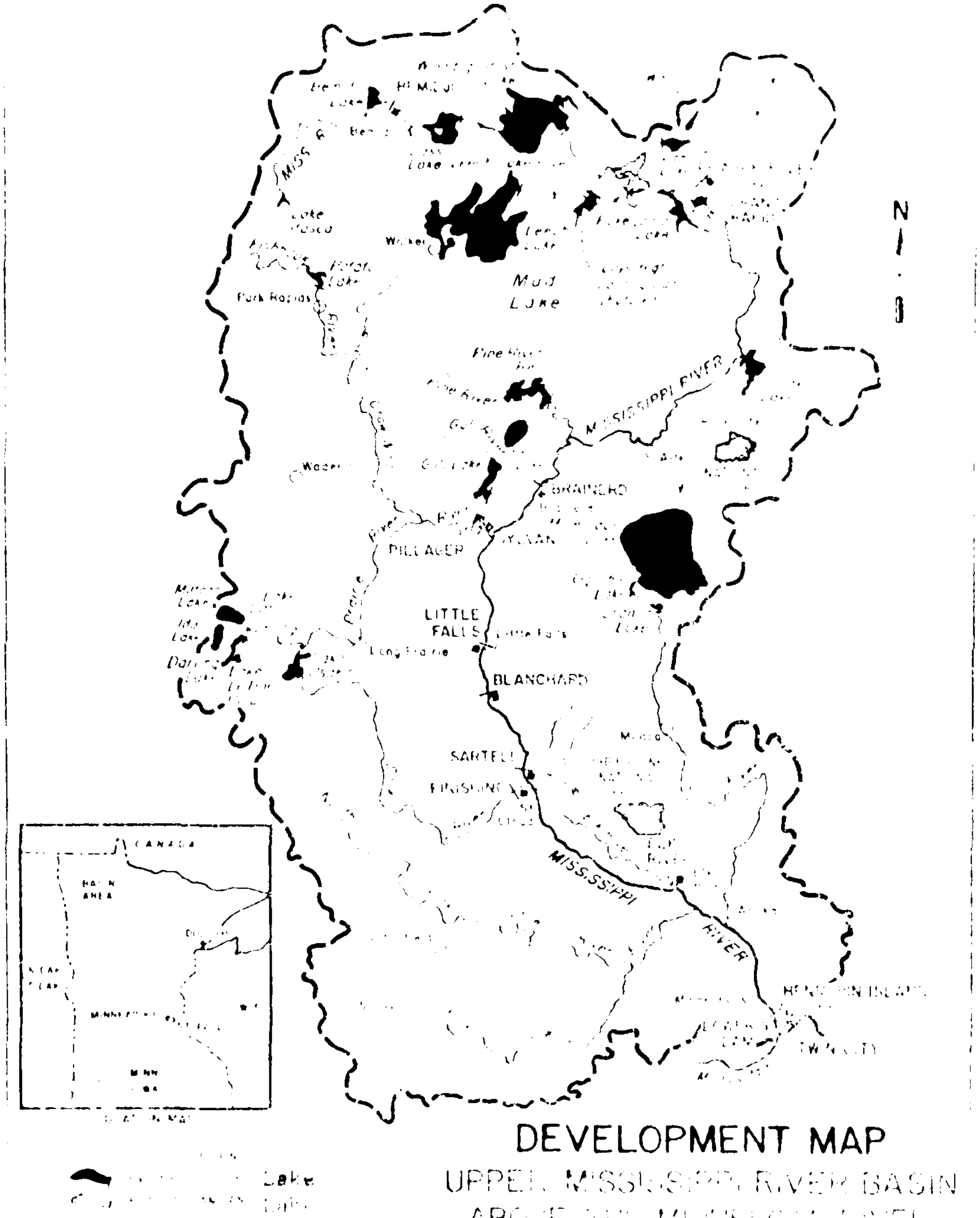
PINE RIVER LAKE DAM



GULL LAKE DAM

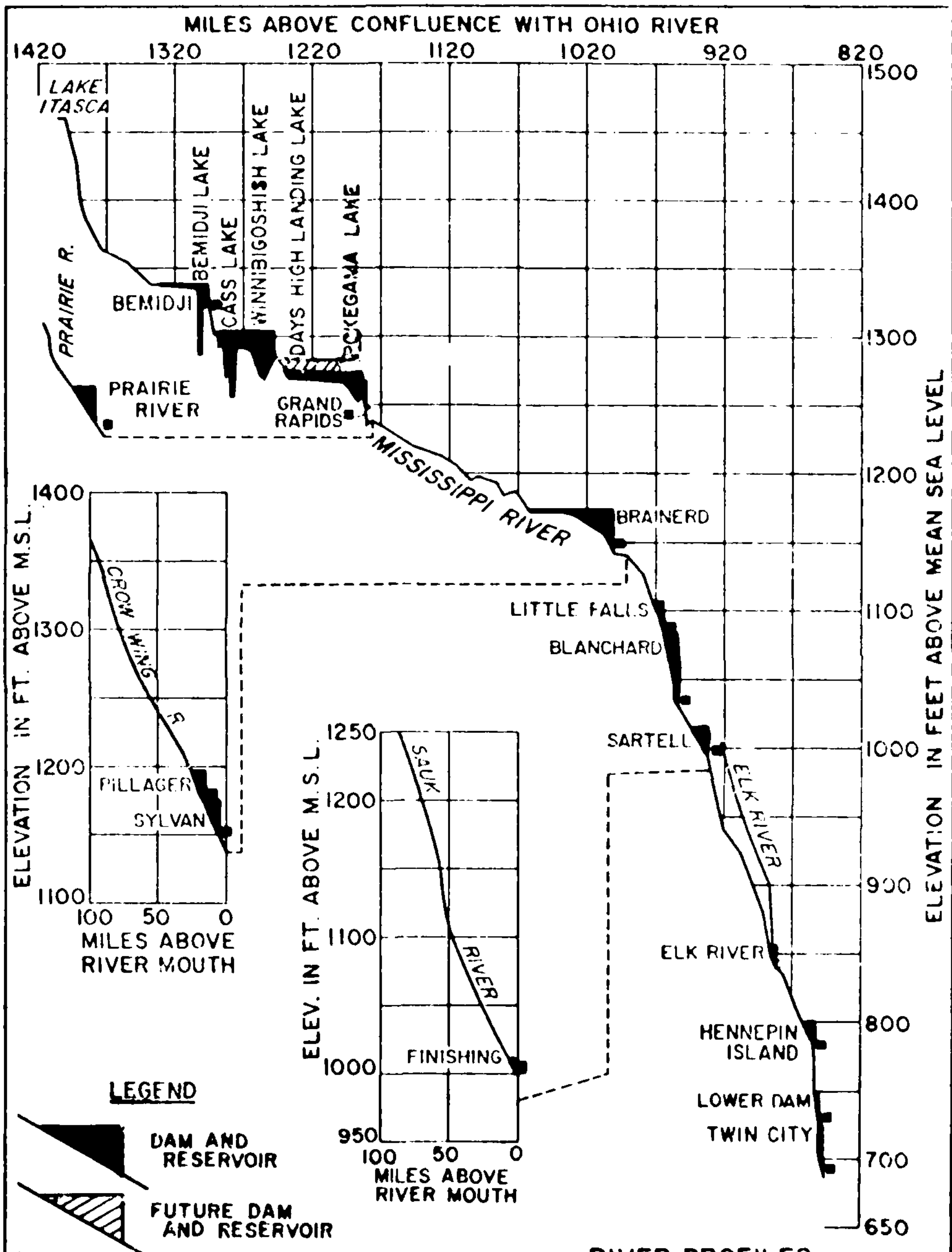
In 1957, the Corps of Engineers completed a flood control diversion channel near Aitkin. Another channel improvement, completed in [illegible], provided channel straightening and partial closing of auxiliary channels for the reach of the Mississippi River between Leech, Winnibigoshish, and Pokegama Lakes.

Three other significant dams in the immediate vicinity of the headwaters lakes are located at the outlets of Lake Bemidji, Cass Lake, and Mud Lake. Lake Bemidji Dam is owned by a power company; Cass Lake Dam is owned by the U.S. Forest Service; and Mud Lake Dam is owned by the State of Minnesota and operated by the Corps of Engineers. Fifteen hydroelectric power plant sites with dams are also located in the Upper Mississippi River basin. However, 2 of the 15 sites are no longer [illegible]. The locations of the above dams along with river profiles and [illegible]tions are shown in the following two figures and table.



DEVELOPMENT MAP

UPPER MISSISSIPPI RIVER BASIN
ABOVE THE MINNESOTA RIVER



RIVER PROFILES
UPPER MISSISSIPPI RIVER BASIN
ABOVE THE MINNESOTA RIVER

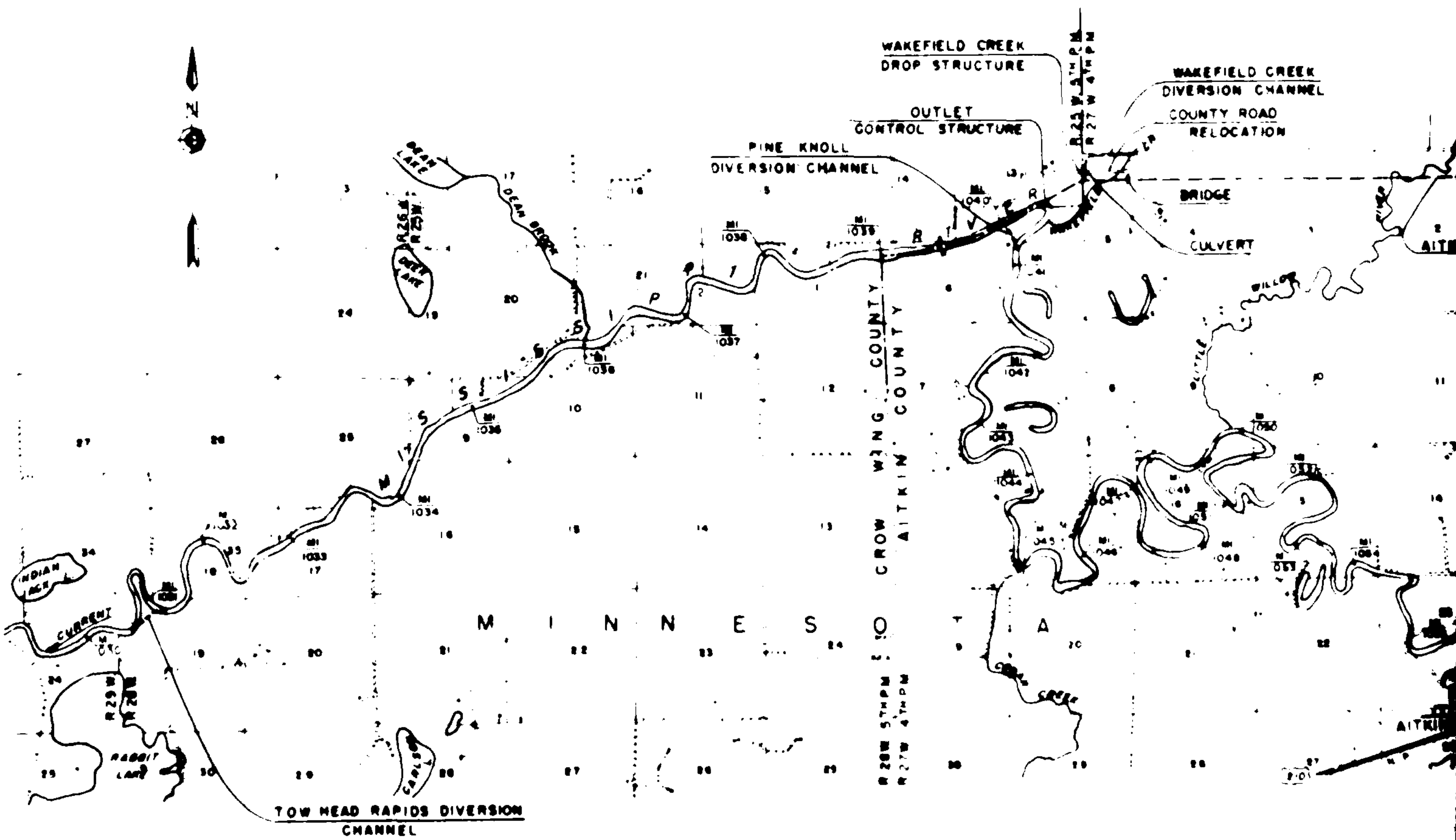
Existing hydroelectric projects, Upper Mississippi River basin above the Minnesota River

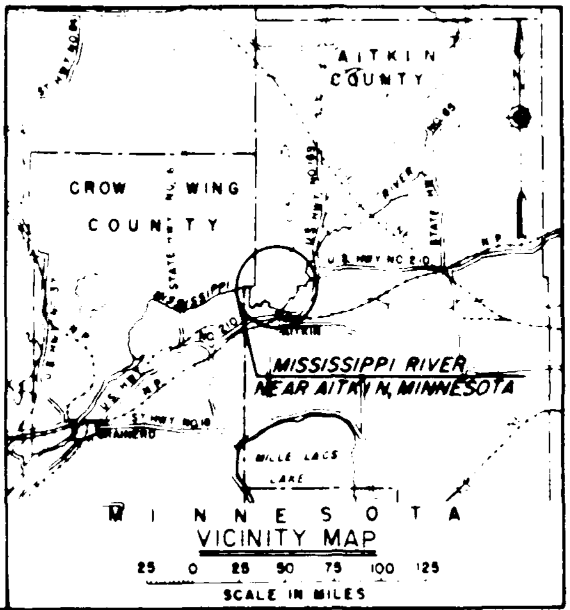
Name of development	River	Owner	Federal Power Commission project number	License expiration date	Drainage area (sq mi)	Maximum gross head (feet)	Installed capacity (kw)	Average annual generation (million kwh)	Date completed
Twin City	Mississippi	Ford Motor Company	362	6 Jun 1973 (1)	19,684	37.9	14,400	87.0	192[illegible]
Lower Dam	Mississippi	Northern States Power Company	2056	31 Dec 2000	19,680	24	8,000	52.3	1897 (2)
Hennepin Island	Mississippi	Northern States Power Company	2056	31 Dec 2000	19,680	49	12,400	91.5	1909 (3)
Elk River (8)	Elk	Elk River Municipal Utility	-		610	15	250	1.0	1916
Fintshing (8)	Sauk	Cold Spring Granite	-		860	9	150	0.1	N/A
Sartell	Mississippi	St. Regis Paper Company	-		12,450	21	2,340 (4)	7.4	1906
Blanchard (7)	Mississippi	Minnesota Power and Light Company	346	24 Aug 1973 (1)	11,425	45	12,000	79.1	1925
Little Falls	Mississippi	Minnesota Power and Light Company	2532	31 Dec 1993	11,145	24	3,520	21.0	1919
Sylvan	Crow Wing	Minnesota Power and Light Company	2454 (5)	31 Dec 1993	3,575	22	1,800	9.8	1913
Pillager	Crow Wing	Minnesota Power and Light Company	2663 (5)		3,230	22	1,520	9.3	1917
Brainerd	Mississippi	Potlatch Corporation	2533		7,320	22	2,800	15.0	1916
Prairie River	Prairie	Blandin Power Company	2361	31 Dec 1993	446	35	1,084	3.4	1921
Grand Rapids	Mississippi	Blandin Paper Company	2362	31 Dec 1993	3,265	20 (6)	2,100	10.0	1901
Bemidji	Mississippi	Otter Tail Power Company	-		610	23	740	2.2	1909
Total							63,104	389.1	

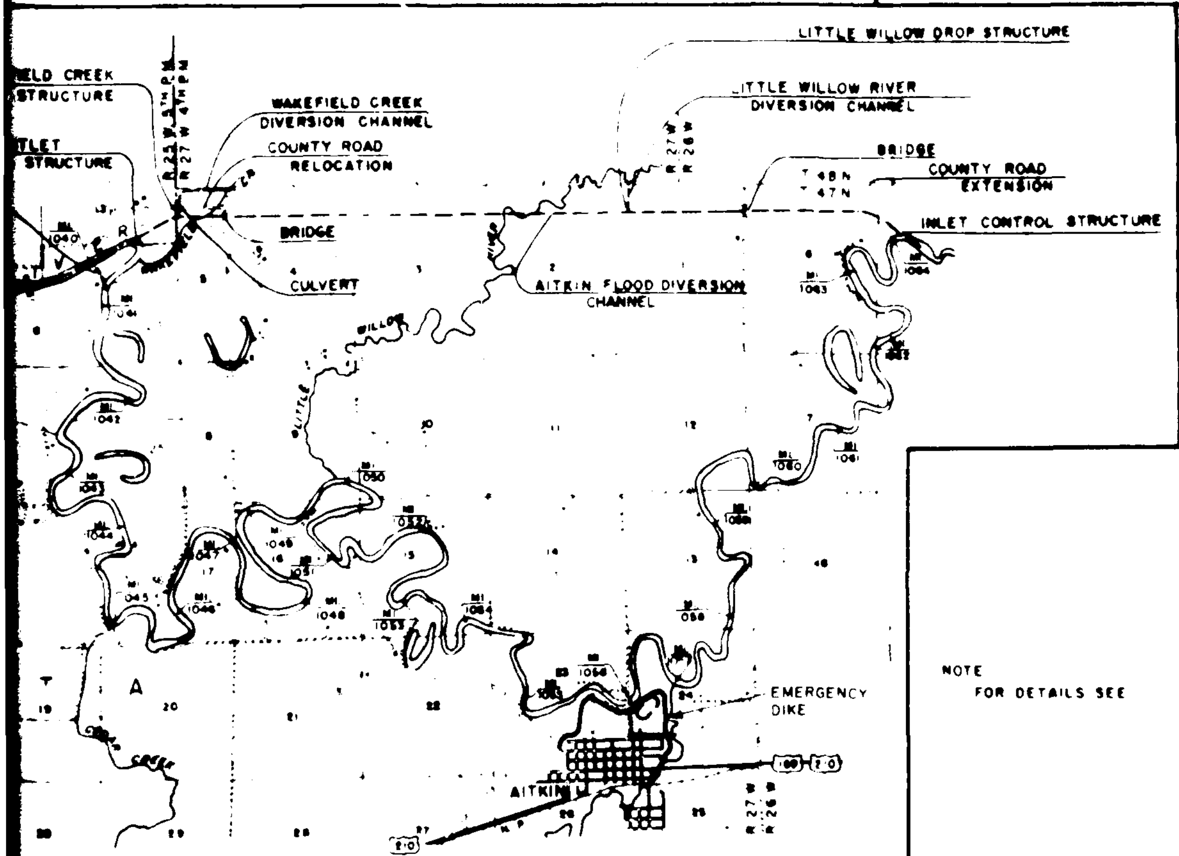
(1) Presently operating under an annual license.
(2) Generating equipment modified in 1952.
(3) Generating equipment modified in 1955.
(4) Plus 5,705 KW hydromechanical.
(5) License application pending.
(6) Design head.
(7) Hennepin Power and Light operates a second dam at this location.
(8) Currently inactive.

FLOOD PROBLEMS

Floods of damaging proportions occur on the Mississippi River above Brainerd as a result of prolonged periods of above normal summer rainfall and rapid snowmelt aided at times by spring rains. The flood problem is somewhat reduced by the natural lakes, marshes, and four of the six federally controlled headwaters lakes. Although the six headwaters lakes were constructed primarily for impounding spring runoff which could later be discharged into the Mississippi River to facilitate downstream navigation, they are now operated primarily for recreation and, where feasible, to reduce flood stages. Damaging floods in the study area occur on the six headwaters lakes, in the vicinity of Aitkin, and on Black Bear and Miller Lakes near Riverton. Location maps for these two areas are shown on the following figures.


WAKEFIELD CREEK
DROP STRUCTURE
WAKEFIELD CREEK
DIVERSION CHANNEL
OUTLET
CONTROL STRUCTURE
COUNTY ROAD
RELOCATION
PINE KNOLL
DIVERSION CHANNEL
BRIDGE
CULVERT
M I S S I S S I P P I R I V E R
CROW WING COUNTY
AITKIN COUNTY
M I N N E S O T A
INDIAN LAKE
CURRENT
RABBIT LAKE
CARLSON
DEAN BROOK
TOW HEAD RAPIDS DIVERSION
CHANNEL

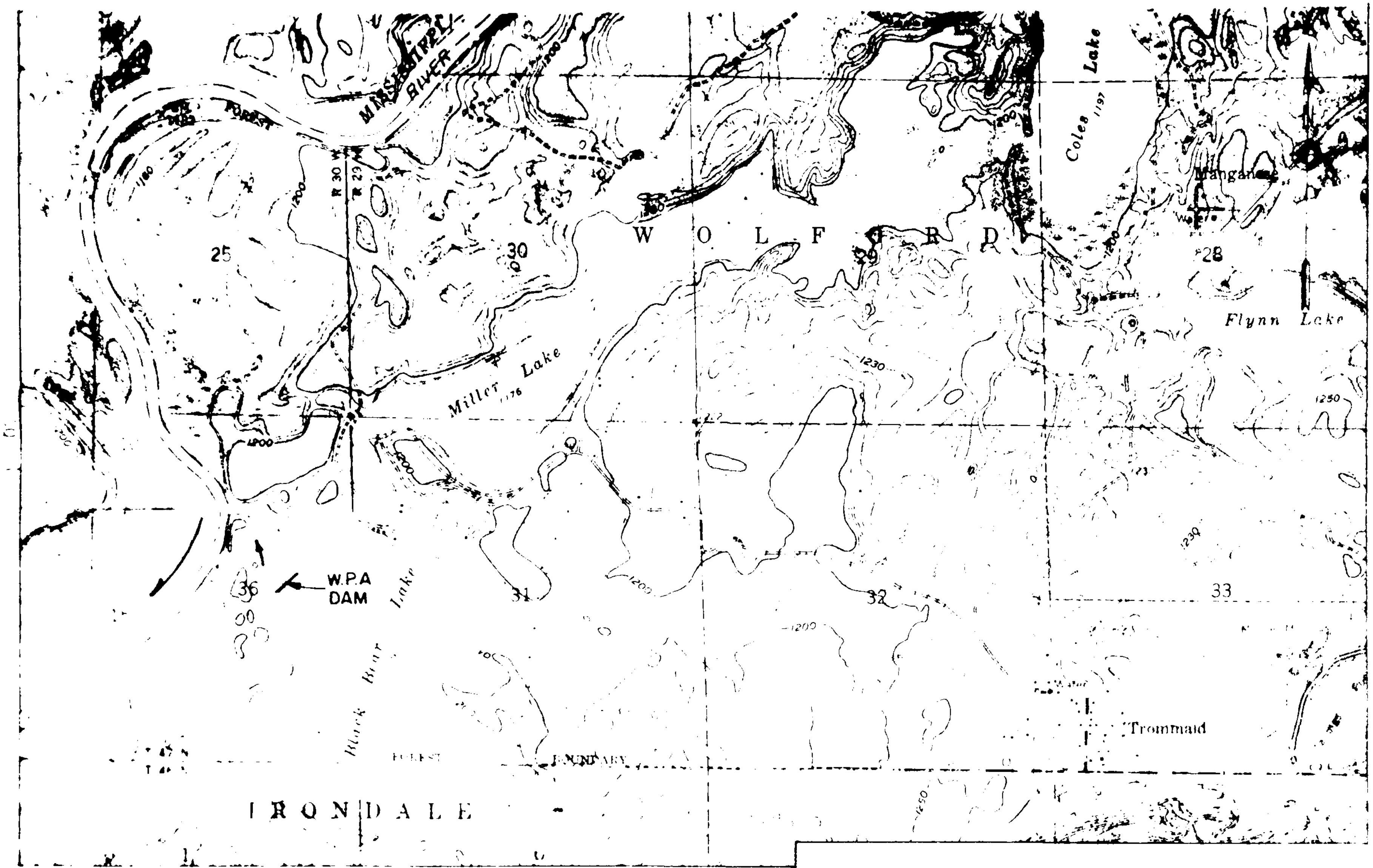




NOTE
FOR DETAILS SEE

PROJECT MAP
FLOOD [illegible]
NEAR AITKIN
CORPS OF ENGINEERS U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER
ST. PAUL DISTRICT ST. PAUL, MINNESOTA

U.S. GPO 1979 665 155 58 6



LOCATION MAP
BLACK BEAR AND MILLER LAKES

ration of the six headwaters lakes during flood periods cannot prevent flooding in the lakes or in the downstream areas. each lake is operated to minimize lake area flooding, and uppermost lakes (Winnibigoshish, Leech, Pokegama, and Sandy) vented damages in the downstream Aitkin area as shown in owing table.

Headwaters lakes - Aitkin area, damages prevented (by year)

Year	Historic flood damages prevented
938-1960	$4,271,400
1962	523,000
1963	0
1964	197,400
1965	230,000
1966	344,000
1967	367,000
1968	66,800
1969	224,300
1970	390,000
1971	416,000
1972	677,100
1973	0
1974	116,600
1975	195,000
1976	0
1977	0
1978	76,400
Total	8,095,000

umulated damages prevented through 1978 by individual lakes n are shown in the following table.

Headwaters lakes - Aitkin area, damages prevented (by lake)

Lake	Flood damage prevented
Winnibigoshish	$3,434,800
Leech	3,722,700
Pokegama	681,000
Sandy	256,500
Pine River	-
Gull	-
Total	8,095,000

The following table compares actual historic dollar damages prevented from 1962 to 1978, historic damages indexed to October 1977 prices, and damages sustained in 1977 prices and level of development at Aitkin. One column also shows total headwaters area flood damages, including damages experienced in the six headwaters lakes.

Headwaters lakes - Aitkin area, damages prevented and sustained

Year	Flood damages prevented				Flood damages sustained[2]	
	By four lakes	By diversion channel	Total	Total (1977 prices)[1]	Aitkin area	Aitkin area and six headwaters lakes
1962	$523,000	$263,200	$786,200	$2,100,000	$402,000	$906,000
1963	0	0	0	0	110,000	182,000
1964	197,400	209,100	406,500	1,025,000	425,000	475,000
1965	230,000	384,700	614,700	1,510,000	715,000	1,379,000
1966	344,000	149,200	493,200	1,170,000	836,000	1,226,000
1967	367,000	94,000	461,000	1,060,000	225,000	329,000
1968	66,800	45,800	112,600	241,000	11,000	182,000
1969	224,300	390,600	614,900	1,200,000	605,000	952,000
1970	390,000	161,600	551,600	1,020,000	380,000	519,000
1971	416,000	199,200	615,200	1,000,000	424,000	637,000
1972	677,100	178,000	855,100	1,260,000	525,000	927,000
1973	0	0	0	0	140,000	473,000
1974	116,600	362,400	479,000	615,000	490,000	796,000
1975	195,000	244,000	439,000	520,000	1,080,000	1,626,000
1976	0	0	0	0	130,000	179,000
1977	0	0	0	0	0	173,000
1978	76,400	328,000	404,400	376,000	215,000	419,000
Total	3,823,600	3,009,800	6,833,400	13,097,000	6,713,000	11,380,000

(1) Historic damages adjusted to October 1977 prices by a ratio of average annual building indexes for each year to the 1977 average index (1545).

(2) Damages based on observed elevations and October 1977 prices and level of development (assumes Aitkin diversion channel effective, but Aitkin emergency dike not effective).

WATER QUALITY AND WATER SUPPLY

The quality and quantity of the water from the Mississippi River Headwaters Lakes are of concern to both lake residents and downstream interests. Water samples taken in 1972 and 1973 from each of the six headwaters lakes indicated water of acceptable quality for use as a public water supply except for Sandy Lake where water was too high in iron and color to warrant general use without treatment.

The water from these lakes also met normal bacteriological expectations in 1973. Bacteriological plate counts were less than 20,000 organisms per 100 milliliters, and coliform organisms were far less than the 50 organisms per 100-milliliter standard which defines water suitable for recreation activities involving total body immersion. The following two tables summarize the headwaters lakes 1973 water quality conditions.

Additional information on water quality, including the Mississippi River downstream to Jacobson, is described in Appendix A, Problem 3, Erosion Problems Downstream of Pokegama Dam, and in Appendix D, Water Quality and Water Supply.

Water quality of lake samples compared with various standards

Parameter	Units(3)	Standards(1) WPC 14 (2B,3B,4A)	WCP 15 (2A,2B,3B)	EPA Domestic use	EPA Fish and wildlife	EPA Agri-culture	Observed average measurement(2) in lakes: Winnibi-goshish	Leech	Pokeg-ama	Sandy	Pine River	Gull
pH		6.5-9.0	6.5-8.5	5.0-9.0	6.5-9.0	-	7.8	7.6	7.6	7.2	7.8	7.6
Dissolved oxygen(4)	mg/l(min)	5.0-7.0	5.0-6.0	-	5.0		(7)	(5)	(6)	(6)	(6)	(5)
Turbidity	Jackson unit(max)	25.0	10.0	-	-	-	3	2	2	4	1	2
Alkalinity	mg/l($CaCO_3$)	-	-	400(max)	20(min)		143	143	144	46	122	104
Nitrate-nitrite N	mg/l(max)	-	-	10.0	-	-	0.1	0.1	0.1	0.1	0.1	0.1
Ammonia N	mg/l(max)	1.0	0.2	-	0.02	-	0.05	0.02	0.04	0.04	0.03	0.03
Dissolved solids	mg/l(max)	-	-	-	-	-	159	163	168	110	124	126
Color(5)	Units(max)	30.0	30.0	75.0	-	-	-	-	-	(100)	(37)	(20)
Sulfate	mg/l(max)	10.0	-	-	-	-	-	-	2	-	9	-
Chromium	ug/l(max)	50.0	20.0	50.0	100	-	<20	<20	<20	<20	<20	<20
Copper	ug/l(max)	10.0	10.0	1,000	-	-	9	8	14	11	11	10
Iron	ug/l(max)	-	-	300	1,000	-	250	200	210	650	200	170
Arsenic	ug/l(max)	-	-	50	-	100	50	30	40	60	30	30

(1) Water Pollution Control (WPC) Standards of the State of Minnesota and the U.S. Environmental Protection Agency (Quality Criteria for Water, July 1976).

(2) Sample data from 1973 Environmental Review Report by Bemidji State University. Concentrations given in parentheses are derived from prior publications.

(3) mg/l = milligrams per liter. ug/l = micrograms per liter.

(4) Dissolved oxygen limits shown **vary for designated annual intervals. Consult WPC 14 and 15 in Appendix D for more specific limits.**

(5) **Platinum - cobalt scale units.**

Microbial composition of water samples (July 1973)

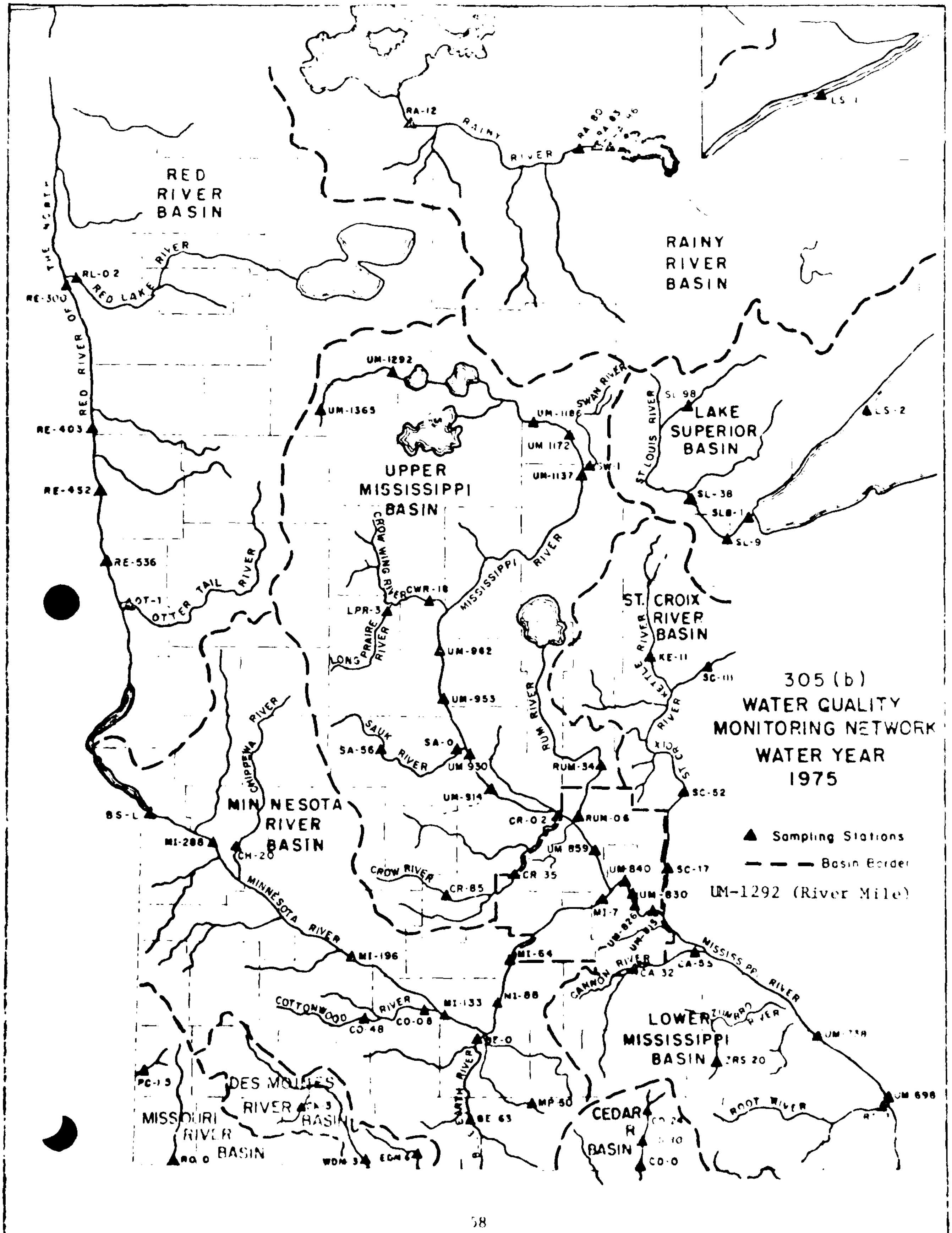
Sample site	Microorganisms per 100 milliliters[1] Total	Coliform	Fecal coliform
Winnibigoshish Lake			
Reservoir	168	1	0
Below dam	4,368	0	0
Leech Lake			
Reservoir	4,956	0	0
Below dam	5,292	0	0
Pokegama Lake			
Reservoir	1,596	0	0
Below dam	3,360	0	0
Sandy Lake			
Reservoir	5,544	0	0
Below dam	3,780	0	0
Pine River Lake			
Reservoir	3,276	1	0
Below dam	2,688	1	0
Gull Lake			
Reservoir	1,764	0	0
Below dam	6,552	0	0
Mississippi River above Brainerd	1,764	0	0

(1) Millipore filter technique.

Total plate counts of less than 20,000 organisms per 100 milliliters are considered acceptable for activities involving total body immersion, such as swimming. Waters having 0 to 50 total coliform organisms per 100 milliliters meet U.S. Public Health Service Standards for use as a water supply with simple chlorination. Waters classified for recreation of all kinds should not exceed 200 most probable number per 100 milliliters (MPN per 100 ml) fecal coliform and water suitable for domestic consumption should not exceed 10 MPN per 100 ml fecal coliform according to Minnesota standards.

Effluent from the Bemidji waste treatment plant was a major concern during the period 1976-77. The city is attempting to upgrade the effluent quality of the system under guidance from the Minnesota Pollution Control Agency. The effluent is discharged into the Mississippi River upstream of the six headwaters lakes.

Currently, 141 municipalities and 96 industrial facilities discharge into surface waters in the basin above St. Paul. The nine monitoring sites maintained by the Minnesota Pollution Control Agency on the Upper Mississippi River main stem portion of the basin show the major water quality problem to be fecal coliform levels. The limiting water quality parameter for fecal coliform levels is 200 MPN per 100 ml and is exceeded 33 percent of the time. The fecal coliform problem is highly localized; the major sources of the problem are concentrated urban areas such as Bemidji, Grand Rapids, and Brainerd. The primary monitoring network operated by the Minnesota Pollution Control Agency in Minnesota is shown on the following location map.


RED RIVER BASIN
RAINY RIVER BASIN
LAKE SUPERIOR BASIN
UPPER MISSISSIPPI BASIN
ST. CROIX RIVER BASIN
MINNESOTA RIVER BASIN
LOWER MISSISSIPPI BASIN
CEDAR R BASIN
DES MOINES RIVER BASIN
MISSOURI RIVER BASIN
RED RIVER OF THE NORTH
RED LAKE RIVER
RAINY RIVER
OTTER TAIL RIVER
CROW WING RIVER
LONG PRAIRIE RIVER
MISSISSIPPI RIVER
SWAN RIVER
ST. LOUIS RIVER
KETTLE RIVER
ST. CROIX
RUM RIVER
SAUK RIVER
CROW RIVER
CHIPPEWA RIVER
MINNESOTA RIVER
COTTONWOOD RIVER
CANNON RIVER
ZUMBRO RIVER
ROOT RIVER
RA-12
RL-0.2
RE-300
RE-403
RE-452
RE-536
OT-1
UM-1292
UM-1365
UM-1186
UM 1172
UM-1137
SW-1
SL 98
LS-1
LS-2
SL-38
SLB-1
SL-9
CWR-18
LPR-3
UM-962
UM-953
KE-11
SC-111
SA-56
SA-0
UM 930
UM-914
RUM-34
SC-52
BS-L
MI-286
CH-20
CR-0.2
RUM-06
UM 859
UM-840
SC-17
CR 35
CR-85
UM-830
MI-7
MI-196
MI-64
CA 32
CA-55
MI-133
MI-88
CO-48
CO-08
BE-0
MP 50
BE 63
ZRS 20
UM 698
PC-1.5
WDM 3
CO-0
305 (b)
WATER QUALITY
MONITORING NETWORK
WATER YEAR
1975
Sampling Stations
Basin Border
UM-1292 (River Mile)

All segments of the Mississippi River are to meet the goals of Public Law 92-500 which calls for attainment of fishable and swimmable waters by 1983.

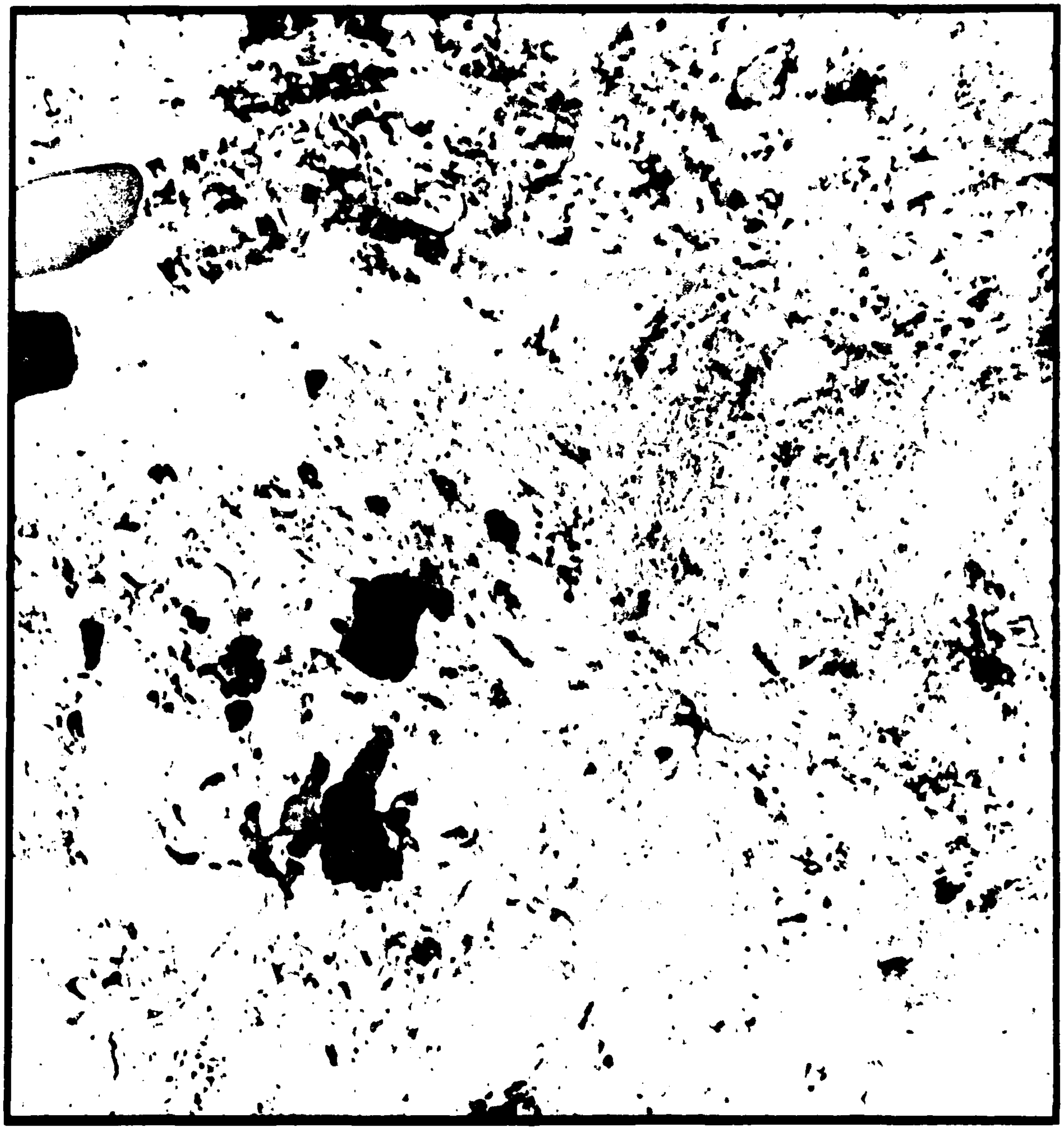
The Metropolitan Council and Twin Cities area officials have indicated they anticipate that water from the headwaters lakes storage or from other sources will be needed to augment low flows in the Twin Cities area some time after the year 2000. Construction of the 9-foot channel Mississippi River navigation dams largely eliminated the need for navigation releases; however, during low-flow periods such as occurred in the summer of 1976, the District Engineer requested voluntary curtailment of lockages. Lockages in the Twin Cities area were actually discontinued for several hours because of insufficient river flow. Headwaters releases were not increased above minimum conservation levels to offset this shortage, but this could have been done if the problem persisted.

The power companies with plants located along the Mississippi River have expressed concern over any change in headwaters lakes releases that could adversely affect power production. Through streamflow regulation from the 6 headwaters lakes, 9 of 15 basin hydropower plants have benefited with increased power output. Also, the seven steam-electric plant above the mouth of the Minnesota River rely on Mississippi River Headwaters releases for a dependable source of cooling water.

A permit system for appropriation of surface water and groundwater in Minnesota has been in effect since 1937. Irrigation permits for withdrawing surface water from the Mississippi River between the Mississippi Headwaters Lakes and St. Paul have increased from 20 mgd (million gallons per day) (30 cfs) in 1970 to 27.4 mgd (42 cfs) in 1977. Based on present trends, it is likely that irrigation withdrawals will continue to increase in the future and may compete with instream users and other withdrawals. The magnitude of the problem will depend on water conservation and water management planning.

The Minnesota Pollution Control Agency completed a land satellite imagery study of much of the Mississippi River Headwaters area in November 1977, in cooperation with the University of Wisconsin and Bendix Aerospace Systems. The study produced colored images showing specific land uses and water quality parameters on 1:250,000 scale maps.

A copy of the September 1976 Land Satellite scene and legend is shown on the following pages.



LANDSAT scene, September 1976

Land Satellite legend

Color	Identification
Color code - water	
Dark blue	Deep, clear water (oligotrophic lakes).
Turquoise	Marl lakes (calcium carbonate particles suspended in water) or other clear water with small amounts of glacial flour, rock flour, or soil particles in it (oligotrophic lakes).
Light green	Non-tannin water with light to medium algae.
Dark green	Medium to heavy algae (eutrophic lakes).
Brown	Brown tannin water or heavy silt/mud suspended in water, sand/mud bottom showing, or light to medium wild rice or other water grasses in shallow water.
White	In lakes: heavy wild rice or other water grasses obscuring the water.
Black	Unclassified.
Color code - land	
Pink	Bare rock or bare concrete.
White	Open disturbed areas (i.e., cities, old mines, etc.) or marsh grass over wetland.
Yellow	Predominantly nonforest open, small thin conifers, or brush.
Light gray	Hardwoods and hardwood/conifer mix.
Dark gray	Conifers.
Black	Unclassified.

The Land Satellite survey and related ground checking is a convenient way to cover a large area and obtain general information on lake water quality at a cost of $2 to $4 per square mile. This type of survey can be used to locate problem areas which can then be analyzed closer with standard water sampling techniques. However, the Land Satellite imagery must be correlated closely with ground observations to distinguish whether a lake such as Pokegama, for example, has a suspended silt problem, is high in tannin, or is covered with wild rice.

The Land Satellite scene for the Mississippi River Headwaters area appears to indicate the characteristics shown in the following table.

Land Satellite identification - Mississippi River Headwaters area

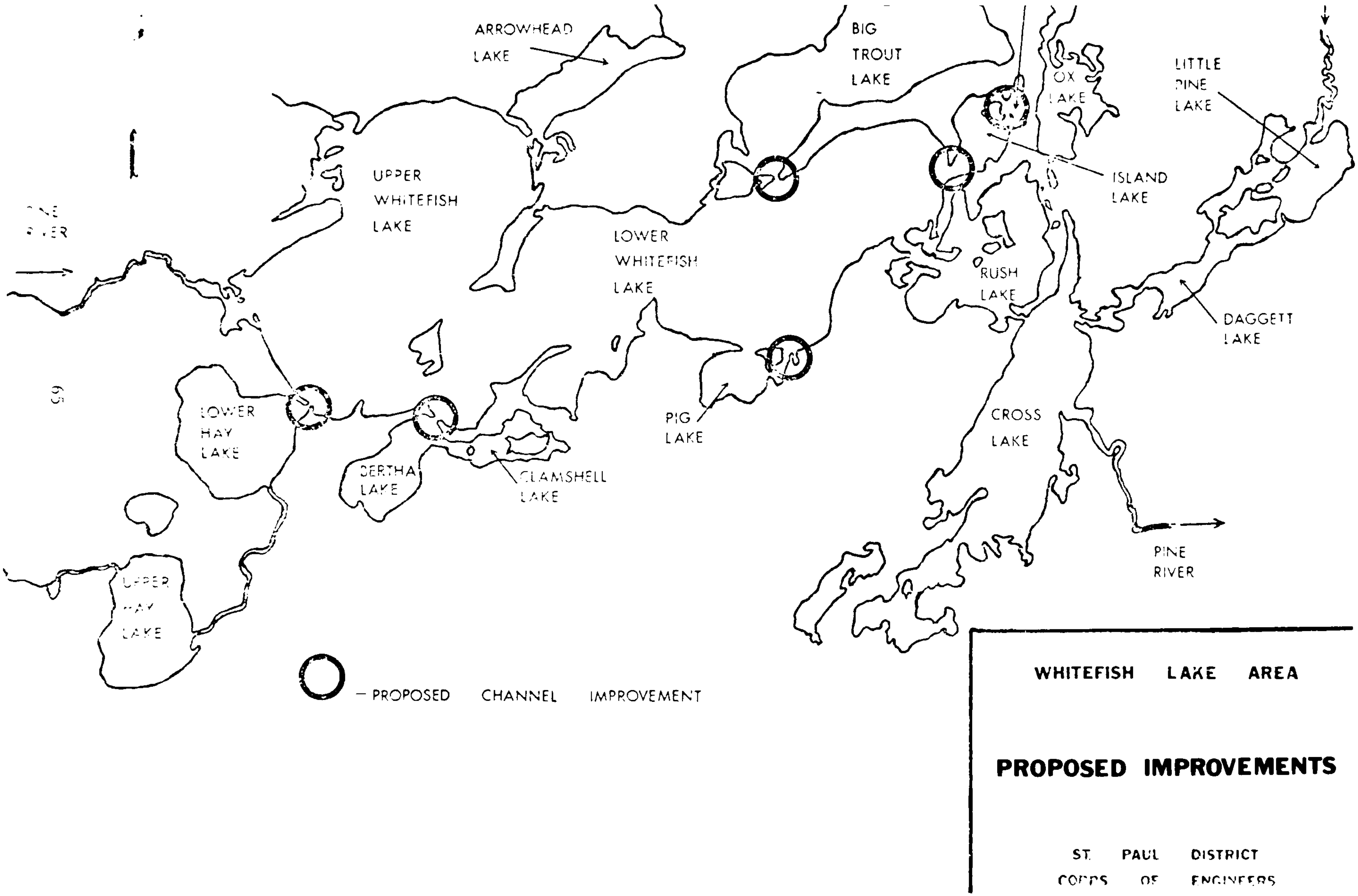
Lake	Color	Identification
Winnibigoshish	Dark blue with brown bonding	Deep lake with lake bottom or suspended silt showing.
Leech	Turquoise to dark blue	Generally a marl lake with several wild rice bays.
Pokegama	Brown	Lake bottom, suspended silt, or tannin showing.
Sandy	Green and brown	Light algae and wild rice.
Pine River (Whitefish chain)	Blue-brown and green	Clear areas, silt or tannin areas, algae areas.
Gull	Not shown	

All six headwaters lakes will be surveyed in a 1-year water quality sampling program begun in September 1978. The work is part of a St. Paul District program to obtain basic data on all impoundments operated by the Corps. The data will be used to determine the need for future water quality sampling, identify potential and existing water problems, and help determine the need for revising present lake operations to improve water quality. The information will be available in a report to be completed by December 1979.

RECREATION

Due to the increased recreation use of the six headwaters lakes, recreationists desire more stable water levels. Lowering maximum operating levels could decrease erosion but, in turn, might produce more problems with access to boat docking facilities and with the lake fisheries. Increased tourist use of the headwaters lakes could increase water nutrient levels and lake eutrophication rates. Increased lake eutrophication rates present a future threat to bottom-dwelling organisms and deepwater fish.

Channel obstructions such as tree stumps and sandbars in the connecting channels between the 12 lakes of the Whitefish Chain present a hazard to boats, particularly during low water level periods such as occurred in 1976. The following map shows proposed channel improvements in the Whitefish Chain.


ARROWHEAD LAKE
BIG TROUT LAKE
OX LAKE
LITTLE PINE LAKE
ISLAND LAKE
UPPER WHITEFISH LAKE
LOWER WHITEFISH LAKE
RUSH LAKE
DAGGETT LAKE
PIG LAKE
CROSS LAKE
LOWER HAY LAKE
BERTHA LAKE
CLAMSHELL LAKE
UPPER HAY LAKE
PINE RIVER
— PROPOSED CHANNEL IMPROVEMENT
WHITEFISH LAKE AREA
PROPOSED IMPROVEMENTS
ST. PAUL DISTRICT
CORPS OF ENGINEERS

In early 1978, congress considered three identical bills (Senate Bill 1697 and House Bills HR 9855 and 10435) to establish the Upper Mississippi River as a Wild and Scenic River under the Federal system. However, the bills were never adopted because of strong local opposition to the Wild and Scenic Rivers concept.

FISH AND WILDLIFE

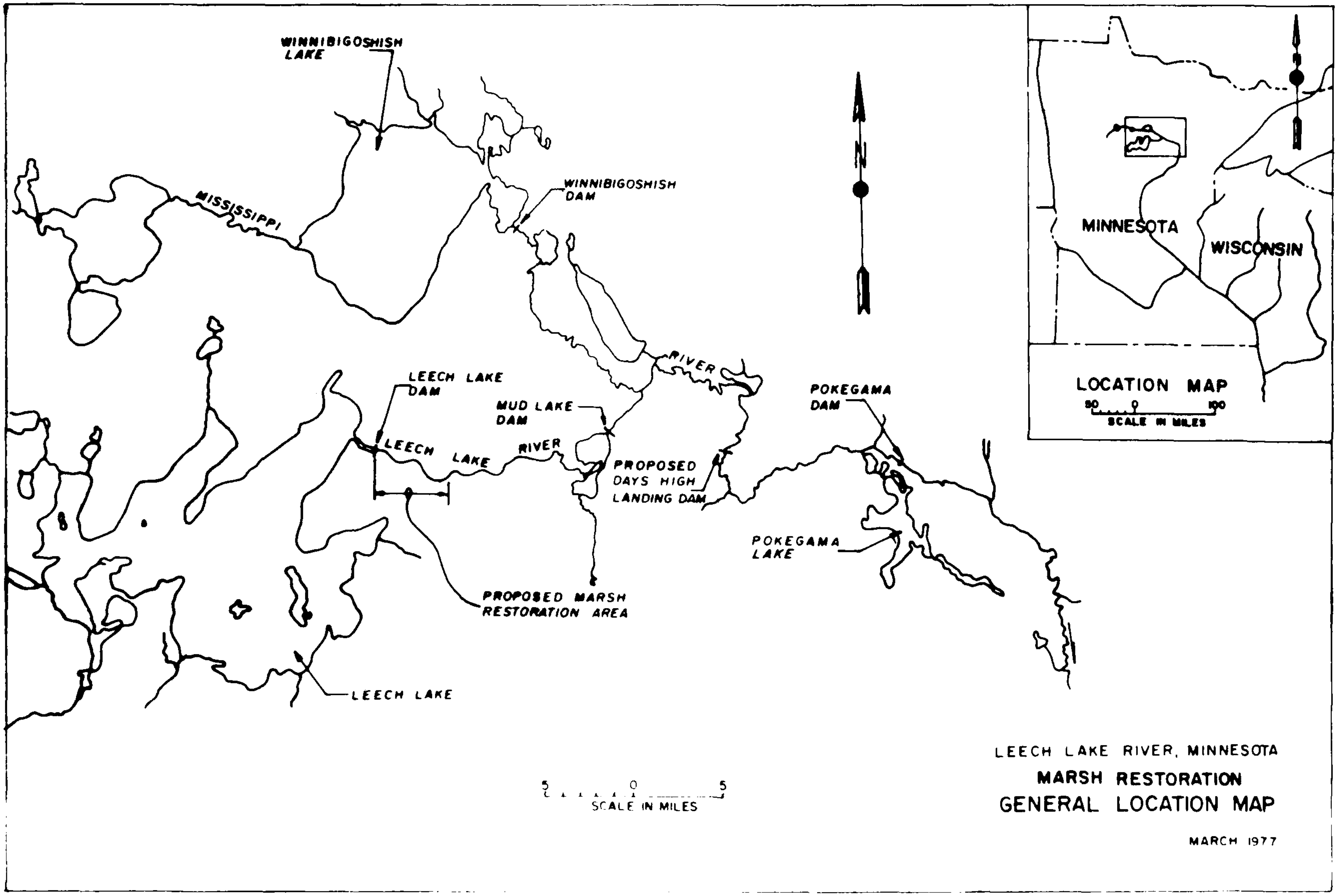
In 1926, the Corps of Engineers completed channel improvements in the area below Leech Lake and Winnibigoshish Dams. This action had an adverse effect on fish and wildlife habitat and on wild rice production. There is now a need to examine mitigation measures necessary to restore the area.

At public meetings in the 1960's, local interests in the headwaters area indicated that low and fluctuating water levels in the White Oak Lake area had detrimental effects on wild rice and fish and wildlife. The St. Paul District studied the feasibility of constructing a dam at Days High Landing to control water levels in the White Oak Lake area. The Corps of Engineers study determined the project to be economically feasible and, in 1972, recommended that the project be authorized for construction. At that time, the State of Minnesota had reservations concerning the project evaluation and requested more survey information. No further study was accomplished on this project due to lack of funds.

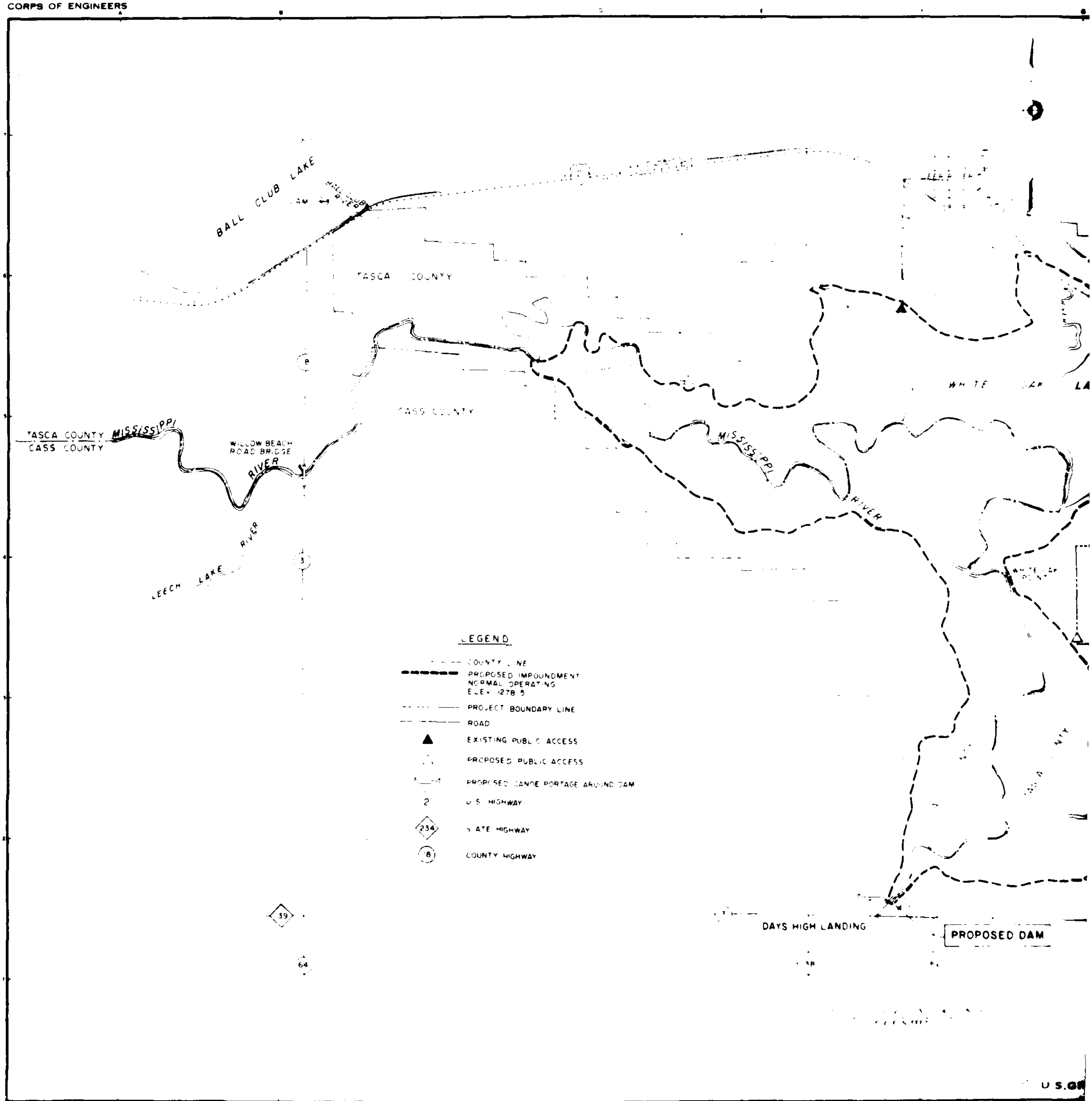
The St. Paul District also developed a plan in 1966 to restore marsh areas lost to channel straightening on the Leech Lake River downstream of Leech Lake Dam. The study was preliminary and no further funding was received.

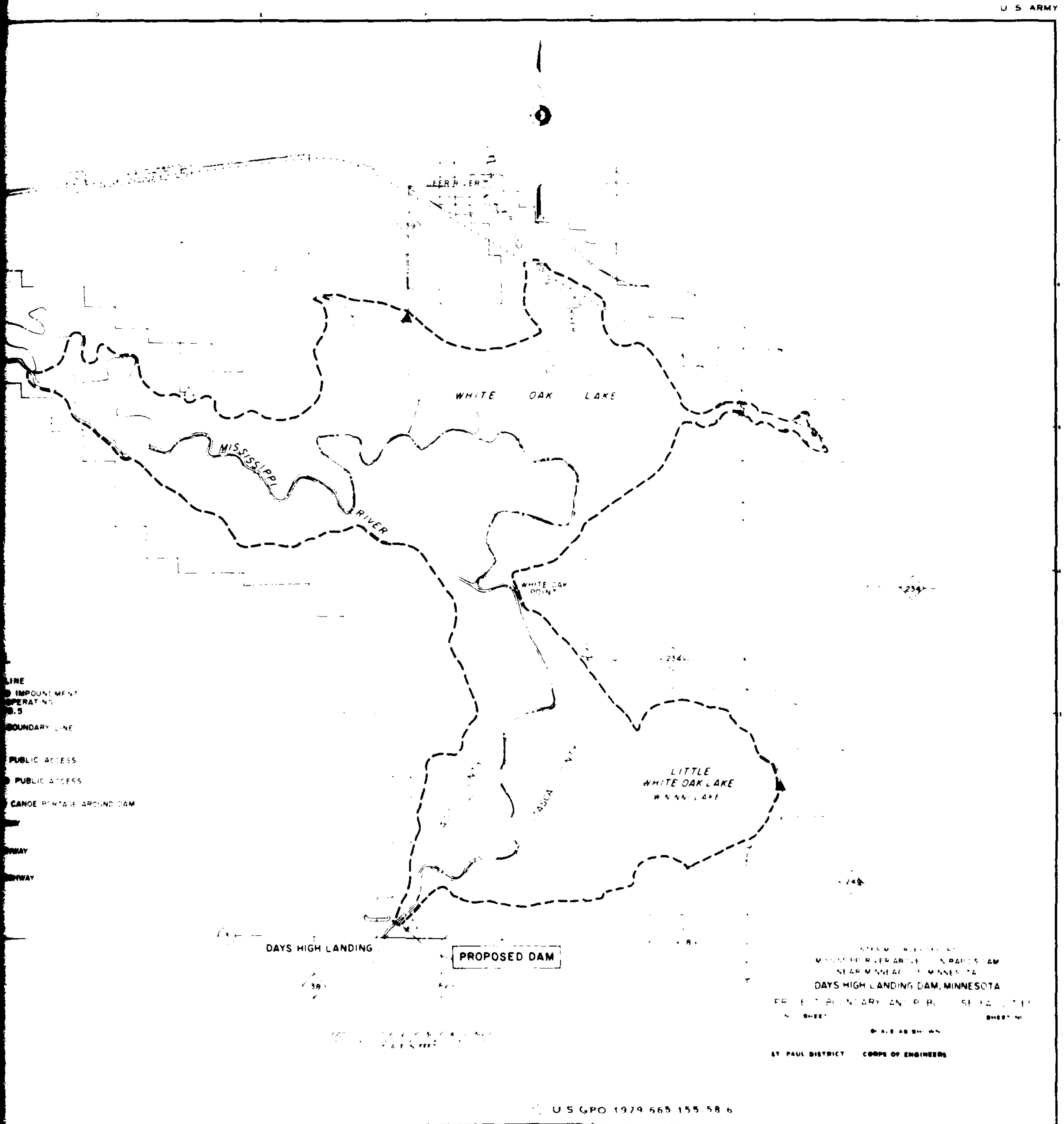
Evaluation and possible revisions of high- and low-flow operating criteria for the six headwaters lakes will consider potential effects on fish and wildlife reproduction and enhancement. The feasibility of a dam at White Oak Lake on the Mississippi River and of marsh diking below Leech Lake Dam on the Leech Lake River will be investigated.

The following two figures show the location of the Leech Lake Marsh and White Oak Dam development proposals.


WINNIBIGOSHISH LAKE
MISSISSIPPI
WINNIBIGOSHISH DAM
RIVER
LEECH LAKE DAM
MUD LAKE DAM
LEECH LAKE RIVER
PROPOSED DAYS HIGH LANDING DAM
POKEGAMA DAM
POKEGAMA LAKE
PROPOSED MARSH RESTORATION AREA
LEECH LAKE
N
MINNESOTA
WISCONSIN
LOCATION MAP
50 0 100
SCALE IN MILES
5 0 5
SCALE IN MILES
LEECH LAKE RIVER, MINNESOTA
MARSH RESTORATION
GENERAL LOCATION MAP
MARCH 1977

CORPS OF ENGINEERS

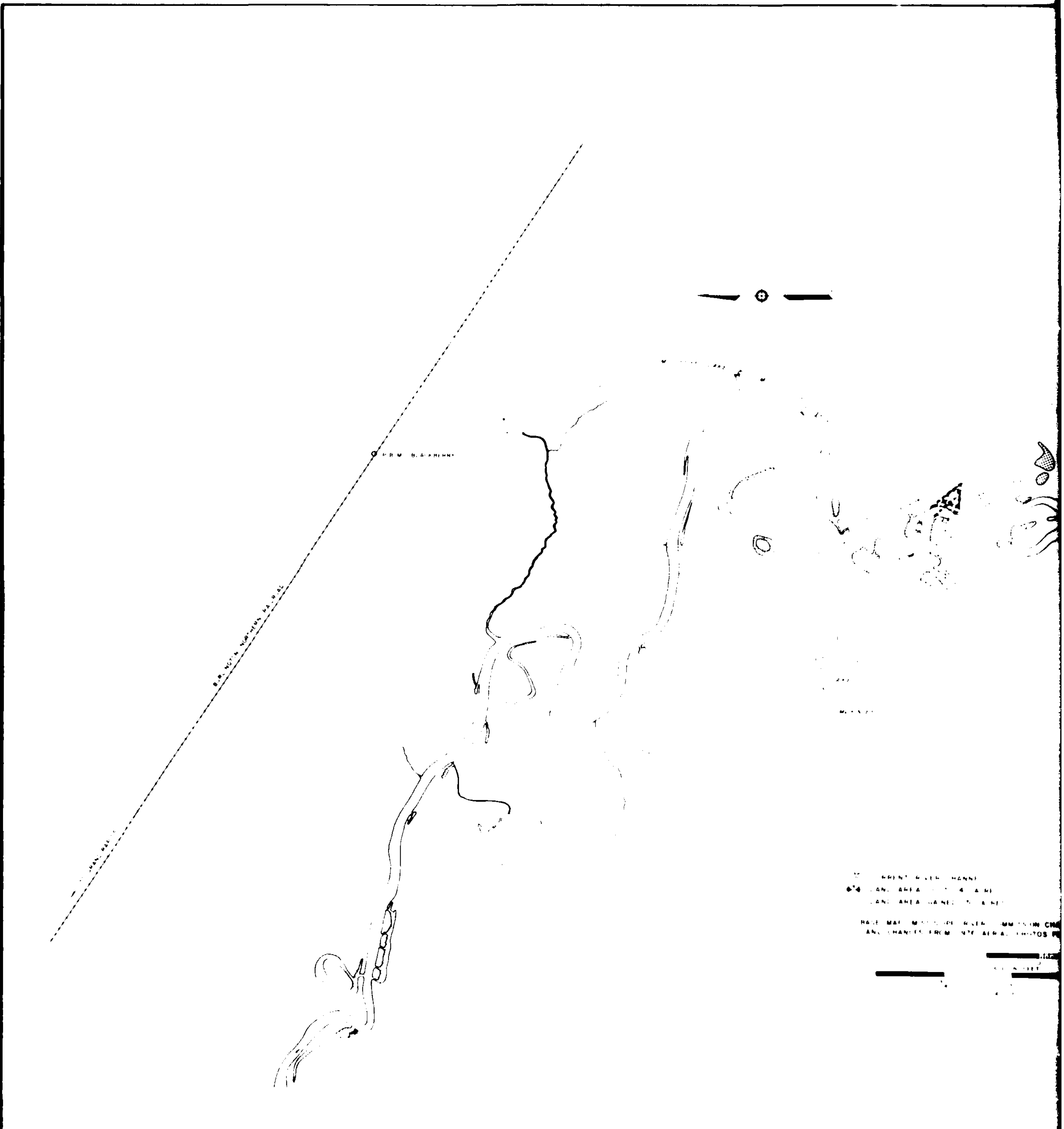


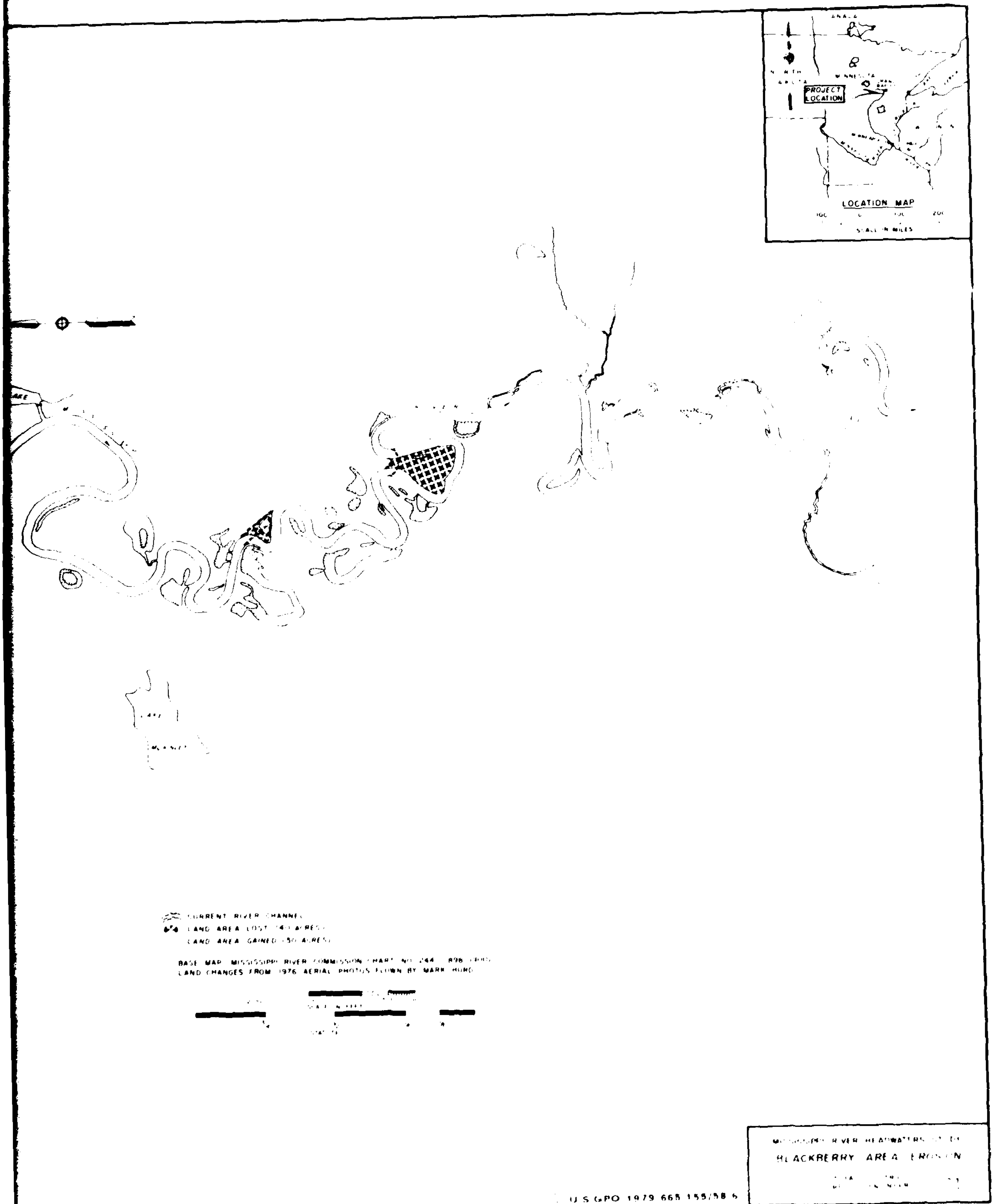

U S ARMY
WHITE OAK LAKE
MISSISSIPPI RIVER
WHITE OAK POINT
LITTLE WHITE OAK LAKE
DAYS HIGH LANDING
PROPOSED DAM
LINE
IMPOUNDMENT
BOUNDARY LINE
PUBLIC ACCESS
PUBLIC ACCESS
CANOE PORTAGE AROUND DAM
DAYS HIGH LANDING DAM, MINNESOTA
ST. PAUL DISTRICT
CORPS OF ENGINEERS
U S GPO 1979 665 155 58 6

BANK EROSION

Bank erosion on the headwaters lakes is caused primarily by high lake levels combined with wind and wave action which accelerate shoreline erosion losses. The progressive loss and deterioration of lakeshore lands and related vegetation can destroy shoreline archeological and cultural sites; damage recreational, residential, and commercial interests; and contribute to degraded water quality. In the Whitefish Lakes chain, bank erosion has produced sandbars which have closed off northern pike spawning marshes and made recreational boat access difficult. A typical erosion problem on Lake Winnibigoshish is shown on the following photograph.

Erosion on Lake Winnibigoshish





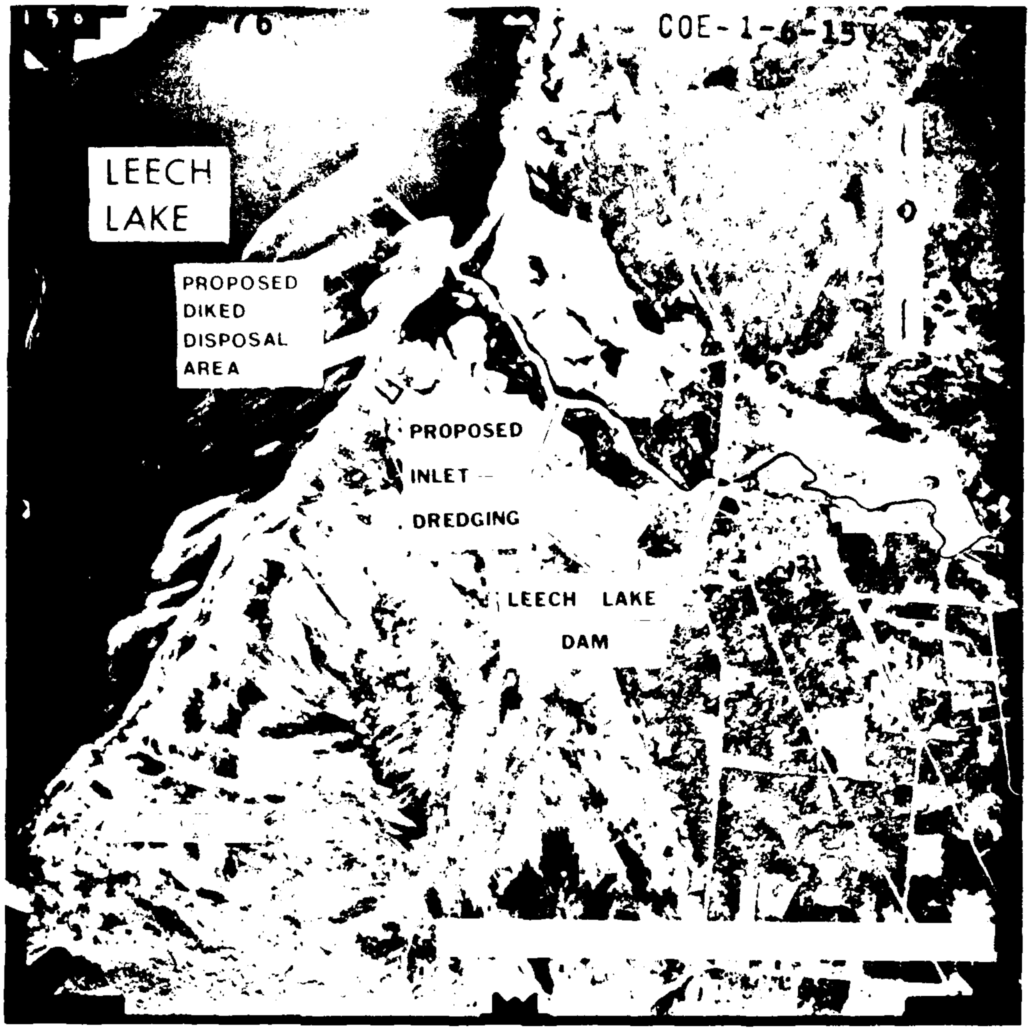
U S GPO 1979 665 155/58 6

Erosion problems also affect an area about 10 miles downstream from Pokegama Dam near the city of Blackberry. The area involves several loops of the Mississippi River which have experienced channel changes. The land is privately owned and is primarily wooded pastureland. The following location map shows the area involved.

Erosion and channel changes are not uncommon in other locations within a 140-mile reach of the Mississippi River from the mouth of the Prairie River downstream from Grand Rapids to Aitkin. Much of the area upstream of Aitkin was once a part of the prehistoric glacial Lake Aitkin, and the river valley is quite flat, with numerous meanders and channel changes.

OTHER PROBLEMS AND NEEDS

A problem occurs with releasing flows in the 1,000-cfs range from Leech Lake Dam when the lake is at or below summer pool level 1294.9. This problem is due in part to the long inlet channel approach (about 1½ miles) which contains abundant weed growth and some floating bogs. These restrictions can cause a head differential of about 1 foot to develop between the lake and the water surface at the structure. The Leech Lake inlet channel is shown on the following aerial view.

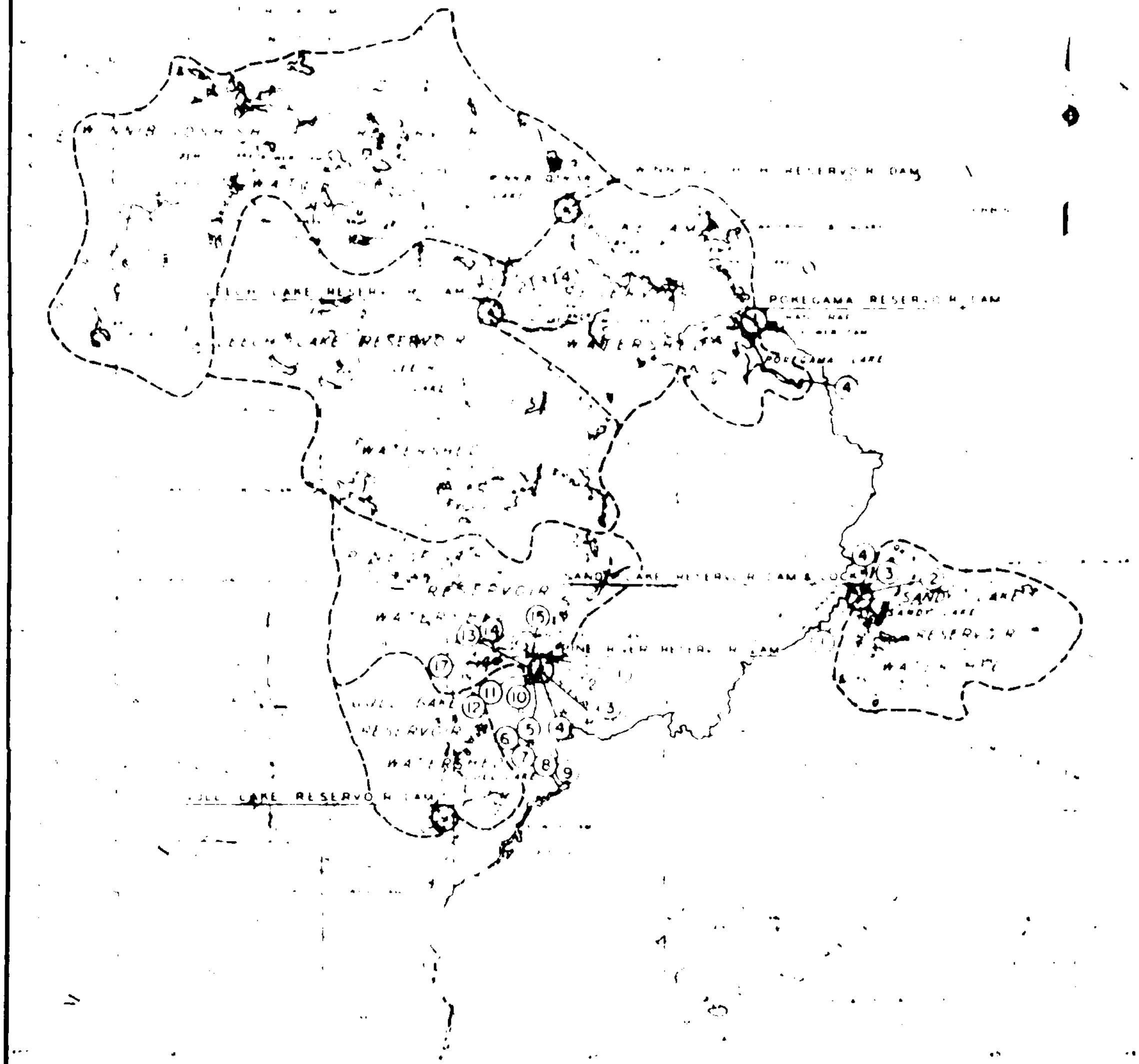

COE-1-6-15
LEECH
LAKE
PROPOSED
DIKED
DISPOSAL
AREA
PROPOSED
INLET
DREDGING
LEECH LAKE
DAM

A major additional concern is wild rice production. Natural wild rice stands are an important source of food and income, especially in the American Indian communities in north central Minnesota. Improvement of water levels for wild rice production should be considered when evaluating any revisions in the Mississippi Headwaters Lakes operating plans.

In general, the 1884 through 1912 headwaters lakes dam construction and subsequent operation have had an adverse effect on early American Indian culture remains. The known archeological and cultural sites on the shorelines controlled by the six Federal dams should be given adequate consideration when possible changes for operating plans are developed. Additional sites that may exist around the lakes should be inventoried.

The rapid increase in the number of permanent and seasonal lake visitors has contributed to a need for more comprehensive shoreland management programs. Land use controls in the headwaters lakes area are currently provided by city, county, and State zoning laws and by Corps of Engineers and State permit authority for development in navigable waters. Uniform shoreline land use controls are desirable for those areas receiving the greatest impact.

Twenty eight perimeter dikes were built around four of the six headwaters lakes in the early 1900's. The dikes were constructed to prevent impounded water from seeking alternate overflow outlets. These dikes have had little, if any, maintenance and are difficult to identify. The present hydrologic value of the dikes should be determined. The structural adequacy of the dikes should be evaluated and the dikes should be properly maintained as impounding structures if they are needed. A map showing the general location of these structures follows.



(4) DIKE NUMBER AND LOCATION

Winnibigoshish Reservoir	Main earth dam-South portion	[illegible]	[illegible]
	Main earth dam-North portion	[illegible]	[illegible]
	Dike No. 1	[illegible]	[illegible]
	Dike No. 2	400	[illegible]
	Dike No. 3	[illegible]	[illegible]
	Dike No. 4	[illegible]	[illegible]
Leech Lake Reservoir	Main earth dam	[illegible]	[illegible]
Pokegama Lake Reservoir	Main earth dam-West portion	[illegible]	[illegible]
	Main earth dam-East portion	[illegible]	[illegible]
	Dike No. 1	[illegible]	[illegible]
Sandy Lake Reservoir	Main earth dam-North portion	[illegible]	[illegible]
	Main earth dam-South portion	[illegible]	[illegible]
	Dike No. 1 (Access road)	[illegible]	[illegible]
	Dike No. 2	[illegible]	[illegible]
	Dike No. 3	[illegible]	[illegible]
	Dike No. 4 [illegible] Lake road	[illegible]	[illegible]
Pine River Reservoir	Main earth dam-East portion	[illegible]	[illegible]
	Main earth dam-East portion	[illegible]	[illegible]
	Dike No. [illegible]	400	[illegible]
	Dike No. [illegible]	[illegible]	[illegible]
	Dike No. [illegible]	800	[illegible]
	Dike No. [illegible]	[illegible]	[illegible]
	Dike No. [illegible]	800	[illegible]
	Dike No. [illegible]	1000	[illegible]
	Dike No. [illegible]	[illegible]	[illegible]
	Dike No. [illegible]	[illegible]	[illegible]
	Dike No. [illegible]	[illegible]	[illegible]
	Dike No. [illegible]	[illegible]	[illegible]
	Dike No. [illegible]	[illegible]	[illegible]
	Dike No. [illegible]	[illegible]	[illegible]
	Dike No. [illegible]	[illegible]	[illegible]
	Dike No. [illegible]	[illegible]	[illegible]
	Dike No. [illegible]	[illegible]	[illegible]
	Dike No. [illegible]	[illegible]	[illegible]
	Dike No. [illegible]	[illegible]	[illegible]
Gull Lake Reservoir	Main earth dam-West portion	[illegible]	[illegible]
	Main earth dam-East portion	[illegible]	[illegible]

MISSISSIPPI RIVER
HEADWATER NAVIGATION RESERVOIRS
EARTH DIKES

OFFICE OF THE DISTRICT ENGINEER
ST. PAUL MINNESOTA

[illegible] sites [illegible] cultural [illegible] historic [illegible] [illegible] the [illegible] controlled headwaters lakes shorelines. These sites were identified in a 197[illegible] Environmental Review of the Mississippi River Headwaters Projects by Bemidji State University. Some of these sites and other subsequently identified sites need protection from lake erosion, vandalism, and unauthorized artifact hunters. All inventoried sites thought to have a potential for providing important scientific and cultural information need to be tested to assess their eligibility for the National Register of Historic Places. Those sites determined eligible for the National Register will require mitigation to preserve the information contained in them.

The structural adequacy of the six headwaters lakes dams should be investigated. The dams currently undergo periodic inspection and repair as part of the normal District operation and maintenance program. A separate detailed design study would be necessary to evaluate the structural adequacy of the principal headwaters dams in greater detail.

DESIRED IMPROVEMENTS

Local interests and, more specifically, property owners on the six controlled lake shorelines desire more stable lake levels. They have indicated that the fluctuations in lake levels increase erosion, decrease or prevent recreation access, and have detrimental effects on wild rice, fish, and wildlife.

Residents of the Aitkin, Pine Knoll, and Cedar Brook areas have indicated the need to extend and upgrade the existing flood control project.

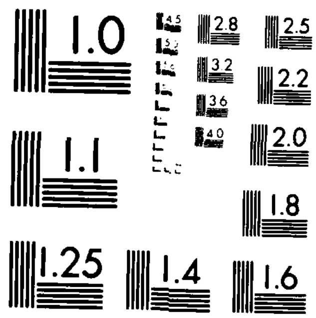
Power interests, including nine hydropower plants and seven steam-electric plants, rely on the Mississippi River for power and cooling waters. Downstream power interests desire reservoir operations that are most favorable to fulfilling their power production needs.

The Minneapolis-St. Paul metropolitan area receives about two-thirds of its water supply from the Mississippi River and could possibly require low-flow augmentation. A critical low-flow situation occurred in the metropolitan area in [illegible] as shown in the following figure.

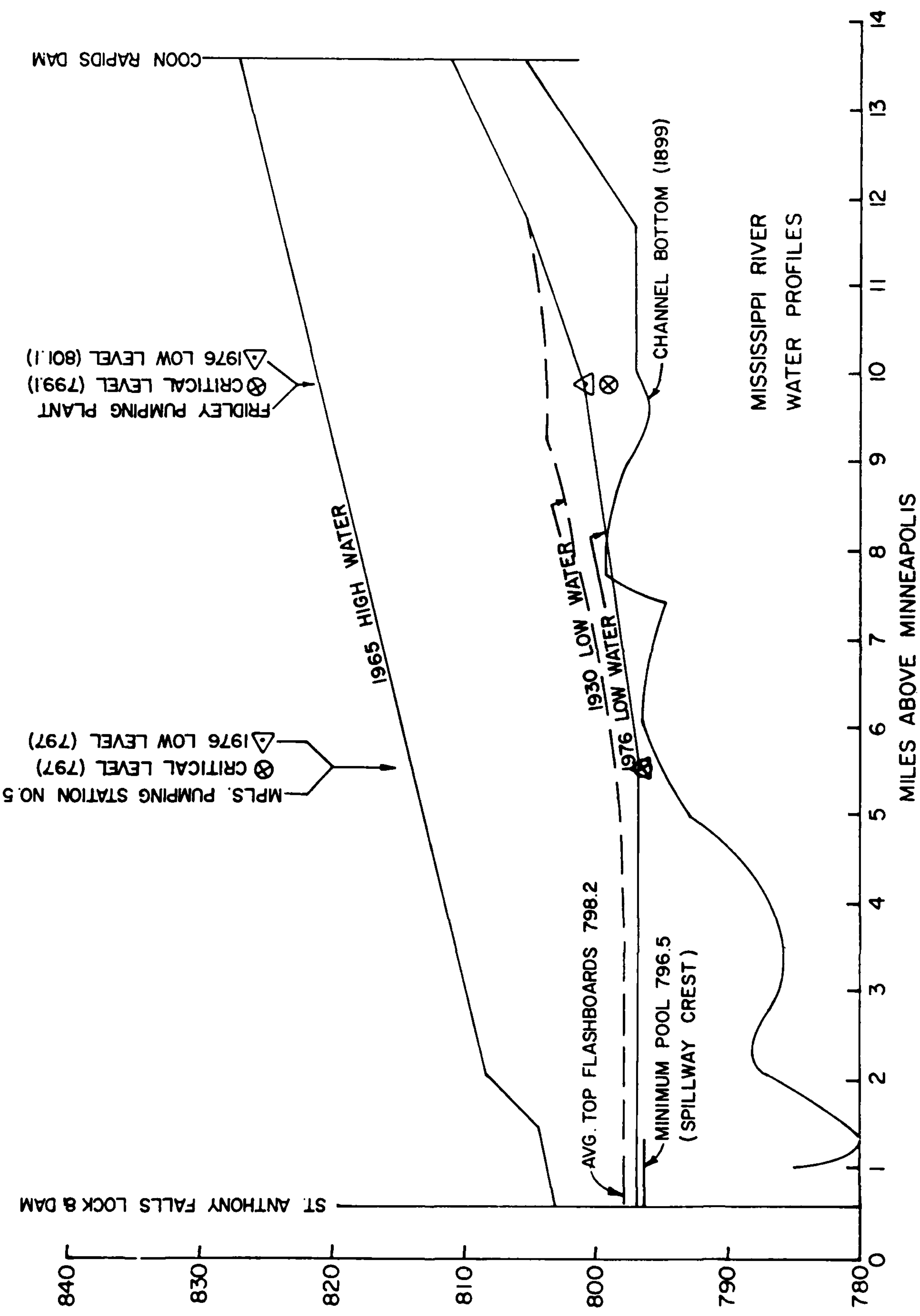
AD-A130 354 MISSISSIPPI RIVER HEADWATERS LAKES IN MINNESOTA FEASIBILITY STUDY MAIN REPORT(U) CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT SEP 82

2/3

UNCLASSIFIED F/G 13/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A



MISSISSIPPI RIVER
WATER PROFILES
MILES ABOVE MINNEAPOLIS
ELEVATION M.S.L. (1912 ADJ.)
COON RAPIDS DAM
ST. ANTHONY FALLS LOCK & DAM
1965 HIGH WATER
1930 LOW WATER
1976 LOW WATER
CHANNEL BOTTOM (1899)
FRIDLEY PUMPING PLANT
CRITICAL LEVEL (799.1)
1976 LOW LEVEL (801.1)
MPLS. PUMPING STATION NO.5
CRITICAL LEVEL (797)
1976 LOW LEVEL (797)
AVG. TOP FLASHBOARDS 798.2
MINIMUM POOL 796.5
(SPILLWAY CREST)

The city of St. Paul now has a Drought Action Plan developed in 1980 through the joint efforts of the city, Corps, and the National Weather Service. Under the St. Paul plan, the city's water supply needs could be reduced by 60 percent in an emergency or drought situation. The plan relies on reduced consumption, increased use of other surface water facilities, and construction of several new high capacity wells. Unfortunately, the city of Minneapolis has not completed such a plan.

PLAN FORMULATION

INTRODUCTION

The purpose of plan formulation is to review the operation of the six Mississippi River Headwaters dams and the related water problems in the basin with the intent of identifying solutions that will meet the objectives identified in the plan of study. The following planning objectives have been identified.

- Develop an optimum operating plan for the six headwaters dams (on a system basis) in the interest of:

  (1) Stable water levels for lake docking facilities.
  (2) Wild rice production upstream and downstream of the dams, water supply, water quality, fish and wildlife conservation, hydropower and power plant cooling water needs, and navigation.
  (3) Bank erosion control on the six headwaters lakes.
  (4) Erosion control downstream of Pokegama Dam.

- Control water levels in the White Oak Lake area for wild rice production, and fish and wildlife conservation.
- Reduce flood damages presently caused by Mississippi River backup on Black Bear and Miller Lakes near Riverton.
- Develop an optimum plan for the headwaters lakes perimeter diking system to insure structural integrity and safety of the system.
- Remove channel obstructions to recreational craft in the Whitefish Lake Chain.
- Remove restrictions in the Leech Lake Dam inlet channel to improve flood release capability.
- Marsh restoration downstream of Leech Lake Dam to facilitate wild rice and furbearer production.
- Flood damage reduction in the Aitkin, Pine Knoll, and Cedar Brook areas.

Plan formulation must also consider the two national planning objectives of economic development and environmental quality. As a minimum, the Principles and Standards require that a national economic development (NED) plan and an environmental quality (EQ) plan be identified. National objectives also require evaluation of a non-structural solution.

Various indirect social constraints guided development of the formulation process in addition to the above specific planning objectives. These social constraints were:

- The plans must be responsive to the desires and needs of the local people and must be acceptable to them.

- The plans should enhance the social well-being of basin residents.

FORMULATION AND EVALUATION CRITERIA

General

Alternatives are developed from the identified list of specific planning objectives; therefore, the alternatives must satisfy some or all of the objectives. Various impacts of developed alternatives were identified by comparing the existing or base condition with the estimated condition with an alternative. For the evaluation of flood control plans, the base condition was identified as floodplain regulation with flood insurance. With respect to reservoir operation plans, the base condition is the existing plan of reservoir operation. Plans affecting other water related problems are evaluated by comparison with a "do nothing" approach.

A standard set of criteria was used to compare the alternatives with the base condition. These criteria are grouped into the following major categories.

a. Technical.

b. Economic.

c. Environmental and social well-being.

Technical Criteria

The following technical criteria were used in formulating alternative plans in accordance with study objectives.

- Plans must be technically feasible to implement.

- Urban flood protection works must be designed to control a standard project flood or, as a minimum, a flood having a chance of occurring once in 100 years (a 1-percent chance flood) or less. Lower level flood control works will be considered in agricultural areas.

- Standard project flood protection will be evaluated.

- Compatible levels of protection will be required in flood protection plans.

Economic Criteria

Economic criteria used in plan formulation are:

- Tangible benefits must exceed project economic costs.

- Each incremental project feature must be economically justified by itself.

- Any recommended plan should provide maximum attainable net benefits.

- Annual benefits and costs for alternatives were derived using an interest rate of 6 5/8 percent and October 1977 price levels and conditions. The benefits and costs so derived were then indexed to current conditions (7 5/8-percent interest and October 1981 prices).

- The project life span that will be used for economic analysis will be the physical life or the economic life of the project feature, whichever is shorter. A period of 100 years will be used for large reservoirs, a major long-term urban flood protection, and levee protection; 50 years will be used for other features.

- A plan that provides less than the economic optimum can be recommended if appropriate gains in environmental quality and social well-being can be shown.

- Local costs of the recommended plan should be within the economic resources of the local interests.

Environmental and Social Well-Being Criteria

The environmental and social well-being criteria used in plan formulation are:

- Any recommended revision of operating plans for the six headwaters lakes must preserve or enhance the quality of the present environment.

- Any proposed structural plan of improvement for flood control or related purposes must also preserve or enhance the quality of the present environment.

- Recommended plans must enhance the economic welfare of the basin population and add to its social well-being.

- Recommended plans should promote minimal disruption of man-made or natural resources, aesthetic values, regional and community cohesion, and public facilities and services.

- Recommended plans must be socially acceptable to the people affected or protected by the plan.

- The local people must be willing and able to provide the necessary cooperation required by the recommended plan.

POSSIBLE SOLUTIONS

General

The purpose of this study is to develop a plan of operation for the six Mississippi River Headwaters dams that will provide the optimum benefit to the many interests affected by operation of these dams. The study will also evaluate solutions to specific problems that are related to operation of the six headwaters dams but cannot be resolved through operation of the dams themselves.

Eight water resource problem areas identified in the plan of study have been expanded to the following 10 categories which will be examined in this plan formulation section.

1. Headwaters lakes operating plans.
2. Bank erosion control on six Mississippi Headwaters Lakes.
3. Erosion problems downstream of Pokegama Dam.
4. White Oak Lake water levels.
5. Black Bear and Miller Lakes flood control.
6. Headwaters lakes perimeter dikes.
7. Whitefish Lakes channel obstructions and marking.
8. Leech Lake Dam inlet channel restrictions.
9. Leech Lake marsh channel cutoffs.
10. Aitkin area flood control.

Possible solutions to each problem have been classified as structural or nonstructural. The general elements of nonstructural and structural alternatives are as follows:

Nonstructural

- No action.
- Flood insurance and floodplain regulations.
- Flood forecasting and warning.
- Revised lake operating plans.
- Flood proofing.
- Flood area evacuation.
- Channel and water hazard marking.

Structural

- Modify existing structures.
- Bank protection and improvements.
- Dams.
- Flood control levees.
- Subimpoundment diking.
- Stump and sandbar removal.
- Diversion channels.

HEADWATERS LAKES OPERATING PLANS - PROBLEM 1

A number of operating plans were evaluated for the six Mississippi River Headwaters Dams. The analysis was conducted in two parts. First, the following four operating plans were analyzed: the present plan of operation, a natural conditions plan, a flood control operation plan for Aitkin, and a water supply plan for the Twin Cities. Second, the same four plans were reevaluated and additional operating plans and variations were evaluated based on input received from interested agencies and the public. The hydrologic, economic, and water quality effects of each operating plan are summarized in this report.

The first four operating plans (plans 1 through 4) were first evaluated in this study using the HEC-5c computer program. The analysis took considerable time because of the difficulty in developing a workable computer model. The results of part 1 of the computer study were included in a September 1979 draft Stage 2 report. A general discussion of the operating rationale for each of the plans follows.

Plan 1 - Present Operating Plan

The present plan of operation is reasonably well suited to satisfy diverse but related interests in stable water levels for lake docking facilities and wild rice production upstream and downstream of the dams, water supply, fish and wildlife conservation, hydropower and power plant cooling water needs, flood control, and navigation. The present plan of operation is the product of continual refinement and adjustments to broad operating limits for each lake. The plan has been developing since the headwaters dams were constructed in the late 1800's and early 1900's. Cumulative refinements and adjustments have been made as a result of public hearings and studies carried out since that time.

The present plan of operation may not be the best for any one purpose, but it provides a balanced approach to meeting the many water related demands and needs of the area. The present study compares the current plan of operation with other operating plans, using the same time period and runoff situations.

Preliminary damage surveys have determined estimates for damages resulting from current headwaters lakes operating plans. The following table summarizes average annual damages for existing conditions and October 1977 price levels as contained in the September 1979 Stage 2 report.

Average annual high water damages for existing conditions at October 1977 price levels

Site	Amount
Lake	
Winnibigoshish	$32,460
Leech	96,085
Pokegama	68,840
Sandy	96,836
Pine River	33,425
Gull	120,140
Subtotal	447,786
Aitkin area	309,600
Total	757,386

Plan 2 - Water Supply Plan for the Twin Cities

The present plan of operation of the headwaters lakes does not provide for separate or special flow releases for Twin Cities municipal or industrial water uses. The proposed alternative allows additional flow releases to insure that flows in the Twin Cities metropolitan area would not drop below approximately 1,600 cfs. (This flow is considered to be the minimum required to meet water supply and steam power needs in the Twin Cities area [illegible] the year 2015). This flow would also meet navigation and irrigation requirements upstream of Anoka. The following table summarizes minimum Upper Mississippi River flow requirements (including the Twin Cities).

Preliminary summary of Upper Mississippi River low-flow water needs, including the Twin Cities

Use	Need (in million gallons per day) 1970	1980	1990	2000	2015
Navigation[1]	225	225	225	225	225
Irrigation upstream of Anoka[2]	20	47	67	87	120
Hydropower and steam electric demands[3]	437	437	437	437	437
Twin Cities area water supply					
Total[4]	306.1	381.2	509.1	679.2	1,010[6]
Surface water only[5]	101.1	151.2	189.1	256.2	485[6]
Amount required to meet surface water needs (irrigation, hydropower, and Twin Cities surface water supply)	558.1 (865 cfs)	635.2 (985 cfs)	693.1 (1,075 cfs)	780.2 (1,210 cfs)	1,042 (1,615 cfs)

(1) Minneapolis-St. Paul Level B Study, June 1977, page IX-3.
(2) 9 September 1964 summary of water quality and irrigation needs by Corps of Engineers.
(3) Based on peak cooling demand at Riverside steam power plant (from Level B, Minneapolis-St. Paul Water Supply Task Group Technical Paper).
(4) Minneapolis-St. Paul Level B Study, June 1977, Page V-5.
(5) From figure 1 (same source as footnote 3).
(6) Extrapolation.

Examination of the Anoka, Minnesota, stream gage flow records for the period 1931-1976 indicates that there were 38 months when the average monthly flow was below 1,600 cfs (year 2015 requirements). The Twin Cities metropolitan area would need headwaters lakes supplementary flow releases during these months if the deficit were to come from Mississippi River flows. During the period of record, supplementary flow releases would have been required in only 3 months to insure a flow rate of 985 cfs (1980 needs) and during only 1 month to insure a flow rate of 865 cfs (1970 needs). The 1 month with flow less than 1970 needs was August 1934.

During 1976, Twin Cities municipal systems (especially Minneapolis) experienced problems with Mississippi River water withdrawals, even though the average monthly flows for August through November 1976 were greater than the estimated 985-cfs average monthly 1980 needs. Two principal factors contributed to the problem: (1) peak Twin Cities daily surface water consumption approached 300 cfs and (2) problems with flow regulation on the Mississippi River disrupted the "run-of-the-river" flow regime at the Twin Cities.

Plan 3 - Flood Control Plan for Aitkin

This proposed alternative evaluates the economic effects of assuming the lakes are to be operated exclusively for flood control at Aitkin without regard to damage to lake property. In contrast, the present approach to providing flood protection for the Aitkin area by controlling outflow from the four upstream lakes (Winnibigoshish, Leech, Pokegama, and Sandy) is limited primarily by established minimum drawdown levels in the lakes, maximum water levels that can be tolerated by lake property owners, hydraulic limitations of channel capacities, and outflow capacities of the control dams. Winnibigoshish and Leech Lakes, the two largest lakes, are operated to provide flood storage early in the spring so that outflows can be reduced to near zero during high stages at Aitkin. Operation of the two lakes farther downstream, Pokegama and Sandy Lakes, is regulated parallel with the observed stages at Aitkin to cause the least total damage in the Pokegama, Sandy, and Aitkin areas.

During floods, the three damage-prone areas of Pokegama, Sandy, and Aitkin are currently operated to follow as closely as possible a rule curve which minimizes total area flood damages and equalizes flood damages between Pokegama and Sandy Lakes. Under the flood control plan, prime importance would be placed on flood protection of the Aitkin area, without regard to upstream lake stability. Spring drawdown of the four upper lakes would be to the original low operating limits or close to them; during floods, water would be stored up to the maximum original operating limit if possible.

Plan 4 - Natural Conditions

This alternative considers the hydrologic results of returning to natural conditions; that is, the conditions with no dams controlling elevations or flows from the six headwaters lakes. This alternative provides a useful comparison for those who might be critical of present operation and think that natural conditions would be better. A natural condition analysis is essential to compare the effects of an operating plan on natural lake levels and flows.

In a practical sense, returning to natural conditions of operation would not be acceptable to lakeshore property owners or to downstream Twin Cities water users. Low water damages to developed properties would increase significantly with this alternative. A return to natural conditions would cause more damage to downstream flood prone residents such as those in the Aitkin area. Natural conditions would probably eliminate bank erosion problems on the six headwaters lakes but would not control or prevent the channel changes that have occurred and will continue to occur between Grand Rapids and Aitkin.

Review of Alternatives

A summary tabulation comparing average annual high and low water losses that would occur with each of the four plans follows. This evaluation was made using the HEC-5c computer program for the September 1979 Stage 2 report.

Operating plan comparison - average annual high and low water losses

Area or location	Operating plan (1977 prices) Plan 1 (present conditions)	Plan 2 (water supply)	Plan 3 (flood control)	Plan 4 (natural conditions
Headwaters lakes				
Winnibigoshish	$32,460	$29,867	$72,746	$97,440
Leech	96,085	125,096	126,445	499,368
Pokegama	68,840	68,262	65,271	55,845
Sandy	96,836	92,557	196,293	407,848
Pine River	33,425	95,580	33,338	698,303
Gull	120,140	164,855	128,155	443,343
Total headwaters lakes	447,486	576,217	622,248	2,202,147
Four upstream lakes (Winnibigoshish, Leech, Pokegama, and Sandy)	294,221	315,782	460,755	1,060,501
Aitkin	309,600	300,520	272,560	453,760
Aitkin plus six headwaters lakes	757,386	876,737	894,808	2,655,907
Anoka	4,488,500	1,104,100	3,631,800	6,119,500
Total	5,245,886	1,980,837	4,526,608	8,775,407

The proportions of high and low water damages shown in the previous table are further reflected in the following table comparing percent damage caused by high and low elevations in the lakes.

Comparison of damages caused by high and low elevations

Plan	Damages (percent) Low elevations	High elevations
Present operating plan	33	67
Natural flows	93	7
Low-flow plan	50	50
High-flow plan	59	41

Individual lake percentages differ from these figures but general trends agree with these data. In summary:

- Two-thirds of the damage under the present operating plan is caused by high lake water surface elevations.

- Ninety-three percent of the damage was caused by low flows with the natural plan. However, if the dams had not been built, it is assumed that many structures would be at a lower elevation and these percentages would change.

- The low-flow plan achieved a good balance between high and low water surface damage (50 percent vs 50 percent).

- The high-flow plan had 59 percent damage with low water surface elevations compared to 41 percent with high elevations. The higher low water damages with this plan are produced by the lower index levels required to provide flood storage.

About 374 graphical plots were developed from the HEC-5c computer program. Data shown in the preceding tables were derived from these plots. The plots are contained in a September 1979 report and appendix prepared by the University of Minnesota's St. Anthony Falls Hydraulic Laboratory (SAFHL). Sample plots comparing alternative plans for Winnibigoshish and Leech Lakes are included in the Design Considerations Appendix of this report.

Stage 2 Problems

The stage 2 study by SAFHL experienced a number of problems with the HEC-5C program that were never completely resolved. SAFHL completed its report which included references to these problems in appendixes H, L, M, and P. The principal focus of the problems lay with the program itself. It was not sufficiently developed to evaluate conditions calling for the headwaters lakes to function independently or together in the manner that was desired.

The St. Paul District decided to further involve the Hydrologic Engineering Center in Davis, California, in expanding the capabilities of the newly upgraded HEC-5 program. A computer analysis was conducted by a private contractor working jointly with HEC to make the HEC-5 program apply to the functional characteristics of the Mississippi River headwaters basin.

Stage 3 Studies

Stage 3 work was directed toward reevaluating the effects of the four operating plans previously evaluated in stage 2 and six additional operating plans which were suggested in or inferred from agency or public comment. The stage 3 computer analysis was done jointly by Anderson-Nichols and Company (ANCO) of Palo Alto, California, and the Hydrologic Engineering Center using the newer HEC-5 model. A brief synopsis of the 10 plans evaluated in stage 3 follows. Plans 1 to 4 are the same as evaluated previously in stage 2 studies (see pages 83 to 86).

- Plan 1 - present operating plan.
- Plan 2 - low-flow plan (water supply plan for the Twin Cities). This plan would insure a minimum flow of 1,600 cfs at Anoka. For further illustration, the 1,600-cfs flow of plan 2 would provide a net 1,450-cfs flow in the Mississippi River under 1970 conditions and a net 850-cfs flow in the Mississippi River in 2015, after total Twin City withdrawals. In comparison, the 7-day 10-year flow at St. Paul, based on past U.S. Geological Survey records, varies from about 1,340 cfs to 1,430 cfs (depending on whether a longer or shorter period

of record is used). Thus, alternative 2 would meet the 7-day 10-year low-flow requirements of St. Paul for 1970, but would be increasingly deficient in that regard for subsequent years.

- Plan 3 - high-flow plan or 15-foot desirable maximum stage at Aitkin (zero damage in the urban area). The four farthest upstream lakes would be operated to protect Aitkin insofar as is possible.

- Plan 4 - natural conditions. The six lakes would be allowed to fluctuate as they did in nature with no control structures present.

- Plan 5 - low-flow plan with 2,275-cfs minimum at Anoka. This alternative would be similar to alternative 2, except the minimum desirable flow at Anoka would be raised from 1,600 to 2,275 cfs.

In letters dated 2 May 1978, the Environmental Protection Agency and the Metropolitan Waste Control Commission both requested evaluation of an alternative with flows of approximately this magnitude. This alternative would ensure 1,875 cfs at St. Paul after Twin City water withdrawals are made. This would be a combined water supply and water quality alternative for supplying year 2000 water needs identified by the June 1977 Minneapolis-St. Paul Level B Study.

- Plan 6 - low-flow plan with 4,800-cfs minimum at Anoka. This alternative would increase the minimum flow at Anoka to 4,800 cfs, using the entire "Present Operating Limits" storage space to provide this flow whenever possible.

In a letter dated 23 May 1978, the Metropolitan Council requested the Corps of Engineers to evaluate a plan which would provide 4,000 cfs at St. Paul (in addition to Twin City water withdrawals). A 4,000-cfs guaranteed minimum low flow at St. Paul would require a delivered flow at Anoka of 4,200 cfs in 1970 and 4,800 cfs in 2015. The purpose of the guaranteed St. Paul low flow of 4,000 cfs would be to provide an assured water supply and water quality improvement in the Twin Cities area and to decrease the required level of sewage treatment (for example, 1983 water quality standards could possibly be maintained without tertiary treatment if the St. Paul 7-day 10-year low-flow were equal to 4,000 cfs or 5,000 cfs).

• Plan 7 - hydropower. This alternative would optimize hydropower production at existing power plants on the Mississippi River upstream of the Twin Cities metropolitan area. It was decided for the purpose of the study that plan 7 would be identical to plan 6 with a desirable minimum flow of 4,800 cfs at Anoka.

• Plan 8 - minimize lake property damage. This alternative should come close to the present operating plan, alternative 1. Potential changes would minimize lake damages, particularly during the recreational season from May to September. No attempt would be made to protect downstream interests at the expense of the lake property owners.

• Plan 9 - environmental or conservation plan. This plan again is quite similar to the present operating plan (alternative 1). Four of the six lakes would be operated as they are now. Leech Lake would be operated to follow the low side of the present operating plan's summer operating band. Generally speaking, a relatively stable level would be required to accommodate wild rice production (see Appendix F, Development of Conservation Plan).

The conservation plan for Lake Winnibigoshish would consist of the present trial operating plan to control lake erosion. This plan attempts to operate Lake Winnibigoshish between 9.0 and 9.5-foot summer levels, with a specific target level of 8.5 by 25 April to facilitate walleye spawning (see Appendix B, pages B-45 to B-46 a).

• Plan 10 - Sandy Lake plan. During spring floods, Sandy Lake gates would be removed from the water sooner to allow the pool and tail water to rise simultaneously from the spring drawdown level. Gates would be closed on the flood recession to maintain its normal pool. Sandy Lake pool is now regulated as it rises from spring drawdown level to normal summer pool because backwater effects from the Mississippi River influence both levels. The objective of the regulation change is to see if it produces any change in damage at Aitkin. The proposed operation change offers advantages to the operators in that it could eliminate considerable gate operation moves without materially changing downstream effects at Aitkin.

Stage 3 Differences

The work in stage 3 followed the same pattern as the stage 2 work except for the following major changes:

- The period of record was extended to include the years 1930 and 1931. These two years were eliminated in stage 2 work because of the lack of U.S. Geological Survey gage records at Anoka. ANCO derived flows at Anoka for these years from three area gages (Elk River, St. Paul, and Mankato).

- The agricultural family of curves expressing the stage-damage relationship at Aitkin was modified by the St. Paul District so it could be used by the HEC-5 program. All curves used in the stage 2 analysis were combined into a single composite urban and rural damage curve.

- Some specifications for lake operations were revised slightly. These changed specifications were detailed in ANCO's report in the discussion of individual operating plans. For example, SAFHL's 1600-cfs low flow release plan (plan 2) contemplated supplemental flows taken from all six headwaters lakes. In the ANCO analysis, only the upper three lakes with the most storage provided the supplemental releases (Winnibigoshish, Leech, and Pokegama). In plan 3, the flood protection plan for Aitkin, SAFHL used Winnibigoshish summer target levels of 10.0 to 10.5 stage which are still the current approved summer level for that lake. However, in actual practice the Corps has attempted to maintain a 1 foot lower range of 9.0 to 9.5 summer level as a part of a trial management period since 1975. Therefore, the ANCO analysis for plan 3 used the 9.0 to 9.5 summer target stage.

Stage 3 Results

The following table presents the results of the stage 3 (ANCO) analysis in the same format as the earlier stage 2 (SAFHL) work (see page 88).

Operating plan comparison - average annual high and low water losses

Area or location	Operating plan (1977 prices)[1] Plan 1 (present conditions)	Plan 2 (water supply)	Plan 3 (flood control)	Plan 4 (natural conditions)	Plan 5 (2,275-cfs flow plan)	Plan 6[3] (4,800-cfs flow plan)	Plan 8 (minimum lake damages)	Plan 9 (conservation plan)
Headwaters lakes								
Winnibigoshish	$13,700	$20,600	$73,400	$90,100	$32,000	$48,000	$10,900	$14,800
Leech	82,300	77,100	176,400	442,500	151,600	162,500	76,800	51,000
Pokegama	27,800	33,000	32,700	56,400	38,000	53,500	5,100	29,900
Sandy	31,500	31,500	138,700	---	31,500	31,500	27,200	31,500
Pine River	22,900	22,900	22,900	618,800	22,900	22,900	15,300	22,900
Gull	142,700	142,000	142,700	498,800	142,700	142,700	87,300	142,700
Total headwaters lakes	320,900	327,800	586,800	1,706,600	418,700	461,100	222,600	292,800
Four upstream lakes (Winnibigoshish, Leech, Pokegama, and Sandy)	155,300	162,200	421,200	589,000	253,100	295,500	120,000	127,200
Aitkin	278,600	278,600	216,800	469,500	278,600	277,700	417,600	283,100
Aitkin plus six headwaters lakes	599,500	606,400	803,600	2,176,100	697,300	738,800	640,200	575,900
Anoka	3,189,900	630,400[2]	3,707,200	5,844,800	6,495,400	109,730,400	3,237,300	2,962,500
Total	3,789,400	1,236,800	4,510,800	8,020,900	7,931,500	110,469,200	3,877,500	3,538,400

(1) The HEC program was not capable of running plan 10. October 1977 prices x 1.34 equals October 1981 prices.

(2) Should be zero. No water shortage occurred at Anoka during the testing period of the study. However, when production runs were made, a slight problem occurred. The problem was corrected by HEC but the correction was made too late in the study to rerun plans 2, 5, and 6.

(3) Plan 7 was identical to plan 6.

No information is listed for plans 7 and 10 since plans 6 and 7 were considered to be identical and plan 10 could not be evaluated with the HEC-5 program because of the Mississippi River backwater conditions that affect the Sandy Lake outlet.

A problem with the above comparison occurs with the low flow release plans 5 and 6. These two plans were attempting to maintain 2,275 cfs and 4,800 cfs at Anoka, respectively. The losses shown at Anoka for these two plans are not therefore directly comparable to plan 2 (1,600 cfs) or the other plans. Consequently, a different manner of comparison had to be developed to properly evaluate the eight plans shown. The following table shows the net economic gain (benefit) or loss (cost) at Anoka for each plan compared to plan 1.

Another problem showed up in the low-flow release plans calling for 1,600, 2,275, and 4,800-cfs minimum flows at Anoka. In effect, the problem prevented some releases that should have been made from the three upper lakes to supply these flows. The problem is not large, but does affect the hydraulic, frequency, and economic results. The expected damage at the three upper lakes should be somewhat larger, and the Anoka requirements should be met more often for plans 2, 5, and 6. The problem was subsequently corrected by HEC, but the plan 2, 5, and 6 results in this report still contain the problem.

Average annual damages and benefits ($1,000's)

Plan	Average annual damages (AAD) Six Res.	Aitkin	Total	Net decrease in AAD (1)	Average annual net benefit at Anoka (2)	Total benefit (2)
1	320.9	278.6	599.5	--	--	--
2 (3)	327.8	278.6	606.4	(6.9)	2,559.5	2,552.6
3	586.8	218.8	803.6	(204.1)	(517.3)	(721.4)
4	1706.6	469.5	2176.1	(1,576.6)	(2,654.9)	(4,231.5)
5 (3)	418.7	278.6	697.3	(97.8)	6034.3	5936.5
6 (3)	461.1	277.7	738.8	(139.3)	12,852.1	12,712.8
8	222.6	417.6	640.2	(40.7)	(47.4)	(88.1)
9	292.8	283.1	575.9	23.6	227.4	251.0

(1) Relative to plan 1. Numbers in parentheses indicate increase in damages.

(2) Relative to plan 1. Numbers in parentheses indicate costs.

(3) Results include HEC-5 program problem as explained on page 95.

Evaluation

The above analysis shows that the best overall plans for individual areas are as follows:

Area	Best plan
Six headwaters lakes	Plan 8 - minimum lake damage
Aitkin area	Plan 3 - flood control
Anoka	Plan 6 - 4,800-cfs low flow
Six headwaters lakes plus Aitkin	Plan 9 - conservation plan

Although plan 1 (present conditions) does not appear as the best plan for any single area, it attempts to consider all interests and therefore benefits all areas without causing extreme hardships to any one specific area.

Also, it should be emphasized that the preceding table compares flood and loss of business damage for the six Mississippi River headwaters areas and Aitkin with potential water supply benefits to the Twin Cities at Anoka. The table does not include numerical losses to wildlife or wild rice crops in the six headwaters lakes, nor does it include potential benefits to pollution abatement as discussed under "Low-Water Damage" in appendix A.

It is interesting to note that the present plan (plan 1) and the 1,600-cfs low flow plan (plan 2) are almost equal in damages in the headwaters lakes ($320,900 vs $327,800). And although plan 8 is best for the six headwaters lakes ($222,600), it would greatly increase Aitkin's average annual damages from $278,600 at present to $417,600. Operating for plan 3, flood control at Aitkin, would result in a similar hardship for the six headwater lakes, causing annual damage there to rise from $320,900 to $586,800. The 4,800-cfs low flow plan (plan 6) would have significant potential water supply (if needed) benefits at Anoka, but to the detriment of the six headwater lakes. Average annual damage in the six lakes would increase from $320,900 to $461,100, although Aitkin would receive a slight benefit from flood control.

The main problem with plan 6 is that this plan is not needed to meet estimated year 2015 low flow water supply requirements in the Twin Cities. The 1,600-cfs plan (plan 2) would suffice. The 4,800-cfs plan could be used in an attempt to avoid tertiary treatment costs for metropolitan area waste disposal. In fact, plan 6 could not meet this requirement at Anoka. Water shortages would occur at Anoka for 187 months (35 percent of the total period of 564 months of simulation) for the 4,800-cfs release attempt. Shortages would occur in months of every year between 1930 and 1976 except 1942, 1944, 1946, 1952, 1954, 1966, 1972, 1973, and 1975.

Plan 5 (2,275-cfs minimum at Anoka) also could not be met at all times during the 1930 to 1976 period. Shortages would occur in 37 out of 564 months, or almost 7 percent of the time. These shortages would occur in the years 1930, 1932, 1933, 1934, 1935, 1936, 1937, 1938, 1940, 1976.

According to the ANCO study, plan 2 (1,600-cfs low flow plan) could provide the required releases during the entire period of record.

The conservation plan, in contrast, would significantly reduce damages in the headwaters grouping (actually at Leech Lake). Headwaters lake damages would decline from $320,900 to $292,800. However, Aitkin damages would increase slightly from $278,600 to $283,100. The added benefit at Anoka would increase by $227,400.

A more revealing look at the effects of the plans at Anoka is provided by comparing the low flow nonexceedance results for each plan. This comparison gives added justification for not attempting to maintain flows at Anoka larger than about 1,600 cfs. The following table is derived from frequency curve plots for the 1930 to 1976 period of record (from the ANCO report).

Comparison of low flow nonexceedance at Anoka

Plan	Anoka 30-day discharge in cfs (for percent nonexceedance)(1)			
	20%	10%	4%	2%
Plan 1 - present plan	1,600	1,150	800	650
Plan 2 - water supply (1,600 cfs)(2)	1,750	1,700	1,300	500
Plan 3 - flood control	1,500	1,000	700	500
Plan 4 - natural conditions	1,350	950	650	500
Plan 5 - water supply (2,275 cfs)	2,050	1,400	900	600
Plan 6 - water supply (4,800 cfs)	1,450	1,000	650	500
Plan 8 - minimum lake damage	1,600	1,150	800	650
Plan 9 - conservation	1,600	1,150	800	650

(1) Nonexceedance is the way low flows are expressed. For example, plan 1 has 1,600 cfs listed under 20 percent for Anoka's 30-day non-exceedance discharge. This means that there is a 20 percent chance that the average 30-day low flow for any given year will not be larger than 1,600 cfs at Anoka. Another way to look at it would be to say that there is an 80 percent chance that the 1,600-cfs 30-day average flow at Anoka will be exceeded for any given year.

(2) The 1,600-cfs goal cannot be met at intervals less frequent than the 6-percent nonexceedance event.

The above table shows that the 10-percent nonexceedance or 10-year, 30-day low flow of 1,700 cfs for plan 2 is better for Anoka than the lesser 10-year, 30-day low flows for plans 5 and 6. Any attempt to maintain flows at Anoka greater than 1,700 cfs would result in more problems with maintaining even the 1,600-cfs flow for the 10-year, 30-day average.

Plans Considered Further

Plans 1, 2, 3, 8, and 9 were all considered further in the analysis. Plan 4 (natural conditions) is not a realistic option from either a practical or economic viewpoint. Plans 5, 6, and 7 are water supply alternatives that require increasingly larger releases to maintain 2,275, 4,800, and 4,300 cfs, respectively, at Anoka. The analysis shows that the six headwater lakes could not physically supply these amounts during the entire period of record. Plan 2 (1,600-cfs flow plan) would be the best choice of the three evaluated water supply plans and would be considered further. Plan 10 involved only Sandy Lake and could not be evaluated by the HEC-5 program.

Contribution of Plans to Specific Planning Objectives

The following table tentatively ranks the plans according to their contributions to specific planning objectives; plans 9 and 1 appear to rank most favorably. The ranking is difficult because of the three major population areas interested in the lake operations: (1) the headwaters lakes area, (2) the Aitkin urban and rural area, and (3) the Twin Cities metropolitan area.

Ranking of plans(1)

Specific planning objectives	Plan satisfaction rating				
	High				Low
Economic feasibility	2	9	1	8	3
Preserve and enhance the quality of the environment	9	8	1	2	3
Enhance economic welfare of the basin population	2	9	1	8	3
Minimize disruption to manmade or natural resources	9	1	2	8	3
Social acceptability	9	1	2	8	3
Local cooperation	9	1	2	8	[illegible]

(1) The plans (designated by number) are summarized on pages [illegible] to [illegible].

Contribution of Plans to National Objectives

The contribution made by each plan to the national objectives of economic development and environmental quality must be evaluated. The Principles and Standards require that a national economic development plan and an environmental quality plan be identified.

The national economic development plan is that plan which maximizes net economic benefits while addressing the range of planning objectives. National economic benefits are determined by measuring and analyzing the net value of increases in goods and services derived from the plan. The national economic development plan is plan 2 (water supply).

An environmental quality plan must provide a net gain in environmental quality through preservation, restoration, or enhancement of resources. No EQ plan has been selected since detailed studies were not conducted. Plans 8 (minimum lake damage) and 9 (conservation plan) would cause the least adverse environmental effects and may be tentatively considered as EQ plans.

Basic studies would be required to determine limiting and controlling factors for natural (versus paddy grown) wild rice. The habitat requirements of commercially and recreationally important fish, as well as their forage species, would need to be investigated before major alterations of lake stages or river flows could be made. Of crucial importance would be spawning and rearing requirements. Changes in the volumes of water in the lake and rivers could have a significant impact on water quality since waste load allocations are based on current operating practices.

If any plans other than the conservation plan (actually a variation within the operating limits of plan 1) were considered for implementation, detailed studies would have to be conducted. Wild rice harvest, commercial and sport fishing, and cultural resource sites would be critical factors to be considered before any alteration of the range and/or timing of lake level fluctuations would be done. Likewise the instream flow needs of fish and potential alterations of water quality would need to be studied before significant changes in the river flow or timing of river stages could be made.

Environmental quality item	Effects of plans on physical impact area Plan 1 - present plan	Plan 2 - water supply	Plan 3 - flood control
Wild and scenic rivers	0 No change	0 Minimal effect on Anoka segment	0 Minimal effect on Anoka segment
Natural streams	0 No change	+2 Additional low flows	+2 Less fluctuation
Beaches	0 No change	0 No change or minimal	-2 Adverse effect
Archeological/historical	0 No change	0 No change	-2 Increase in ero-sion from greater fluctuation
Social	0 No change	0 No change or mini-mal slight effect	-2 Adversely affects larger population group
Aesthetic values	0 No change	-1 Slight effect on lake residents	-2 Detrimental to lake residents
Open space	0 No change	0 No change	No change
Land quality	0 No change	-1 Some loss in some lakes	-2 Upstream exceeds downstream losses
Recreation	0 No change	-1 Slightly detrimental	-1 Slightly detrimental
Air quality and noise	0 No change	0 No change	0 No change
Streambank erosion	0 No change	0 No change	+1 Decreases downstream fluctuation
Water quality	0 No change	+2 Downstream quality improvement	+1 Some increase in downstream supply
Effect on lakes	0 No change	-1 Moderate detrimental effect	-2 Large detrimental effect
Biological resources	0 No change	-1 Minimum lake effects	-2 Greater lake fluc-tuation
Rare and endangered species	0 No change	0 No known effect	0 No known effect
Ecological systems			
Terrestrial	0 No change	0 Minor land increase	-2 More frequent shoreline flooding
Aquatic	0 No change	+1 Slight downstream increase	-2 Frequent lake fluctuation
Preservation of freedom of choice for future resource use	0 No change	-2 Unlikely to reverse	-2 Unlikely to reverse
Total	- = 0 0 = 18 + = 0	- = 7 0 = 9 + = 5	- = 21 0 = 4 + = 4

Key: -2 = Significant loss or long-term effect. +1 = Slight gain or short-term effect.
-1 = Slight loss or short-term effect. +2 = Significant gain or long-term effect.
0 = Status quo.

Effects of alternatives on physical area [illegible]

Environmental quality item	Plan [illegible] – Minimum lake damage	[illegible]
Wild and scenic rivers	0 Minimal effect [illegible] segment	[illegible]
Natural streams	-2 Greater fluctuation	[illegible]
Beaches	+2 Minimize fluctuations	+[illegible] Leech [illegible]
Archeological/historical	+1 Minimizes fluctuations	[illegible]
Social	+1 Minimizes fluctuations and effects on local economy	+2 [illegible] effect [illegible] Indian [illegible]
Aesthetic values	+1 Beneficial to lake residents	[illegible] Minimal change
Open space	0 No change	[illegible]
Land quality	-2 Larger downstream losses offset upstream gains	+2 Large upstream gain, small downstream [illegible]
Recreation	+2 More beneficial to lakes	0 No change
Air quality and noise	0 No change	0 No change
Streambank erosion	-1 Increases downstream fluctuation	0 Minimal change [illegible] Leech
Water quality	-1 Decreases downstream quantity/quality	0 Minimal change
Effect on lakes	+2 Significant benefit	+2 Significant benefit to Leech Lake
Biological resources	+1 Moderate benefit	+2 Significant benefit to wild rice/waterfowl
Rare and endangered species	0 No known effect	0 No known effect
Ecological systems		
Terrestrial	+1 Less frequent shoreline flooding	0 No significant change
Aquatic	+2 Large benefit	+2 Large benefit to Leech
Preservation of freedom of choice for future resource use	-2 Unlikely to reverse	+1 Flexibility intact
Total	– = 8 0 = 4 + = 13	– = 0 0 = 10 + = 13

Key: -2 = Significant loss or long-term effect.
-1 = Slight loss or short-term effect.
0 = Status quo.
+1 = Slight gain or short-term effect.
+2 = Significant gain or long-term effect.

Summary

No benefit-cost ratio analysis is appropriate to this analysis. However, an analysis of upstream damages or potential losses to water supply at Anoka provides a good comparison of alternatives.

With regard to the tables on the preceeding pages, for the stage 2 and stage 3 summary analyses, it is clear from a purely economic standpoint that a change in operation could be justified, such as maintaining a 1,600-cfs minimum flow at Anoka at all times (plan 2). The study results show that 1,600-cfs could be maintained at Anoka during the entire 47-year period of record through supplemental releases from Winnibigoshish, Leech, and Pokegama Lakes. Average annual lake losses would increase by only $7,000 total; Aitkin would not be affected; and the benefits to Anoka (Twin Cities) for water supply would increase by about 2.5 million dollars over the current operation plan. However, when the environmental, social, and political consequences of adopting the plan as a permanent procedure are considered, the economic argument is not the controlling factor.

In summary, it would seem desirable to continue operating the six headwaters lakes much as they are under the present plan (plan 1) or a variation of the conservation plan (plan 9), which is within the limits of the present operating plan. The target levels proposed by the Department of Natural Resources for improving the fishery in Winnibigoshish Lake and by the Leech Lake Tribe for wild rice production in Leech Lake (plan 9) should be implemented in the operating schedule for the next 5 years. If this operating plan is still acceptable after that time, it should be formalized by means of a public hearing and/or notice.

Cultural Resources

There are numerous significant archaeological sites in the headwaters lakes area. Many of these sites are severely eroded, although in some instances the erosion has stabilized. Changes to the present operating plan of the headwaters lakes could increase erosion thus increasing impacts to sites.

The Corps has conducted surveys to identify these sites and to assess erosion problems in some areas of the headwaters region, but not all sites in the area have been located.

Of the 10 alternatives considered in stage 3, only plan 3, which involves operating the lakes for flood control at Aitkin, would have a severe impact on sites by significantly increasing shoreline erosion, the primary threat to sites in the area. None of the other alternatives would increase impacts beyond those already occurring. Alternatives 4 and 8 could potentially lessen impacts by minimizing erosion. However, any action taken to implement any proposed plan could have impacts on cultural resources beyond those outlined above. Prior to implementation, additional surveys will need to be conducted within the headwaters area. All sites located, as well as the known sites that may be affected by the proposed project, will need to be tested to determine their significance. All significant sites listed on or eligible for inclusion on the National Register of Historic Places will need to be mitigated in accordance with Advisory Council on Historic Preservation regulations 36 CFR 800.

Social Impacts

Of the four plans considered in detail, the present operating plan (plan 1), with the changes presented in plan 9, is preferred from the standpoint of social effects. Although plans 1 and 9 do not respond completely to any of the areas of social concern, they represent compromise operating plans which meet to an acceptable level the needs of the partially conflicting concerns. The effects of the plans are summarized in the following table and paragraphs.

Summary of social impacts

Concern	Operating plan							
	1 (1)	2	3	4	5	6	8	9
Erosion - effects on aesthetics and recreation industry	0	-1	-2	-3	-2	-3	-1	+1
Wild rice - effects on native American population	0	-1	-3	-3	-2	-3	+1	+1
Flood control - social effects	0	0	-2	-3	-3	-3	-1	+1

(1) The values of the present operating plan are set at zero (existing conditions) for comparative purposes. This does not imply the absence of effects in these areas of concern.

Bank Erosion and Recreation. - Adverse social impacts that result from bank erosion on the headwaters lakes include effects on aesthetic values, community cohesion, property values, and business activities. The scenic quality of the headwaters lakes is an important social and economic resource of the area. Bank erosion detracts from the aesthetic quality of that resource. Erosion has not yet given nonresident recreationists an overall perception of aesthetic degradation. If erosion continues at present rates, however, perceptions of deterioration could result in severe secondary impacts on the recreation industry and private recreational users. Bank erosion is also affecting property values on the perimeter of the reservoirs. In some areas, as much as 1 foot of shoreline is lost to erosion each year (slumping has affected as much as 10 feet per year). Not only does this result in a direct land (and land value) loss, but it also negatively affects private docks and boathouses. Loss of land and land value has contributed to high levels of controversy and conflict among area residents. Moreover, because erosion is being induced by fluctuating water levels, local residents and marina operators blame the Corps for their losses. Since the Government holds flowage easements on the eroding land, no additional compensation for lost land has been provided.

Plans 1, 2, 8, and 9 would have the fewest negative consequences on continued erosion. The planned alteration in the present Leech Lake operating plan under plans 1 and 9 would help minimize the problem by keeping operations in the low end of the current summer operating range. None of the plans, including plan 3, would increase erosion problems significantly beyond current levels. However, plan 3 would require greater fluctuations on those occasions when it is necessary to draw down for expected spring runoff. These drawdowns would have severe effects on recreation. Plans 5 and 6 would also have severe effects on recreation. The increased release rates (over those of plan 2, the other low flow plan) would result in greater variations in pool levels and more frequent fluctuations. Plan 4 would have the most severe effects on recreation. By returning operations to natural conditions, this plan would make no attempt to stabilize pool levels. The resulting natural fluctuations would contribute to significantly decreased recreation and its attendant adverse social consequences.

Effects on Wild Rice Production. - Wild rice is an important cash crop and foodstuff for the Leech Lake Reservation members. Wild rice production requires stable water levels during June and July and sufficient water levels in August to support harvesting. In the past, production has been adversely affected by fluctuating water levels, resulting in significant decreases in crop yields. This loss is particularly significant in light of the already substandard income of the Leech Lake tribe ($559 per capita income in 1968).

Plans 1, 8, and 9 would have the most beneficial effects on wild rice production. These plans would incorporate minor modifications within existing operating constraints to make improvements over present conditions. Plan 2's effects on wild rice would be similar to those of plan 1. Low flow augmentation would require maintaining relatively high water levels in early summer followed by infrequent and minimal drawdowns in the summer if augmentation is needed. The other low flow augmentation plans, 5 and 6, would have more severe effects because of their higher release rates and greater fluctuations.

Plans 3 and 4 would have the most severe impact on wild rice. The significant fluctuations required for flood control and the anticipated periods of high and low water levels would be inconsistent with the requirements of maximum wild rice production.

Flood Control. - Although the six lakes were constructed originally to augment low-flow navigation, they are now operated primarily for recreation and reduction of flood damages. The majority of damages occur in the Aitkin and Riverton areas. Even when the reservoirs are operated for flood control, the area still suffers significant residual flood damages. In addition, fluctuation of pool levels for maximal floodwater retention would conflict with recreational and other uses which require stable water levels and further contribute to erosion problems at the lakes. Adverse social effects accrue from flooding downstream of the reservoirs; however, the social benefits deriving from a partial reduction in flood stages in these areas would not outweigh the social liabilities to other legimate concerns on and around the lakes. The decision to continue the present operating plan considered the social effects of competing uses for these resources, with a particular concern for maximizing equity in the distribution of costs and benefits among the affected groups and individuals.

Plan 3 was designated the "flood control alternative" in the computer analysis. This plan would minimize damages at Aitkin, but would produce proportionately higher damages in the four upstream headwaters lakes. These higher damages would result from increased drawdown levels required to accommodate anticipated flood storage needed to protect Aitkin.

Plans 1, 2, 5, 6, and 9 would have similar high water damage effects in the six headwaters lakes and at Aitkin. Plan 9 would cause slightly higher damages at Aitkin while reducing high and low water damages in Leech Lake. Although plan 4 would decrease headwaters lakes flood damages, it would drastically increase Aitkin flood damages and low water damages in the headwaters lakes. Plan 8 would decrease headwaters lakes flood damages, but would increase Aitkin flood damages in a similar manner as plan 4.

In terms of net overall effects on high and low water damages in the combined headwaters lakes-Aitkin area, plan 4 would have the most negative effects followed in order by plans 3, 6, 5, 8, 2, 1, and 9. In summary, plans 1 and 9 would be the most socially beneficial plans. They would provide the best combination of benefits to the various conflicting areas of concern.

Recommendations

The SAFHL and ANCO analyses conducted in stage 2 and stage 3 of the Mississippi River Headwaters study were sufficiently thorough to draw conclusions as to the effects of possible lake operating changes. It was decided to maintain the present operating plan (plan 1) and incorporate a variation of the conservation plan (plan 9), which is within the limits of the present operating plan. Operating plan 2 (water supply plan) could be used in emergencies without causing a great deal of loss in the upper three lakes.

The conservation plan (plan 9) evaluated in this study involves a stable water level of 1294.4 from 15 May to 10 September each year. The present operating plan's (plan 1) minimum summer level is 1294.5. At a 13 April 1982 meeting with the Leech Lake Reservation Business Committee it was agreed that the Corps would attempt to stabilize the Leech Lake level no higher than 1294.7, if possible. Since it is physically impossible to maintain a completely stable water level, the agreement would involve attempting to operate on the low side of the present (plan 1) operating range of 1294.5 to 1294.9.

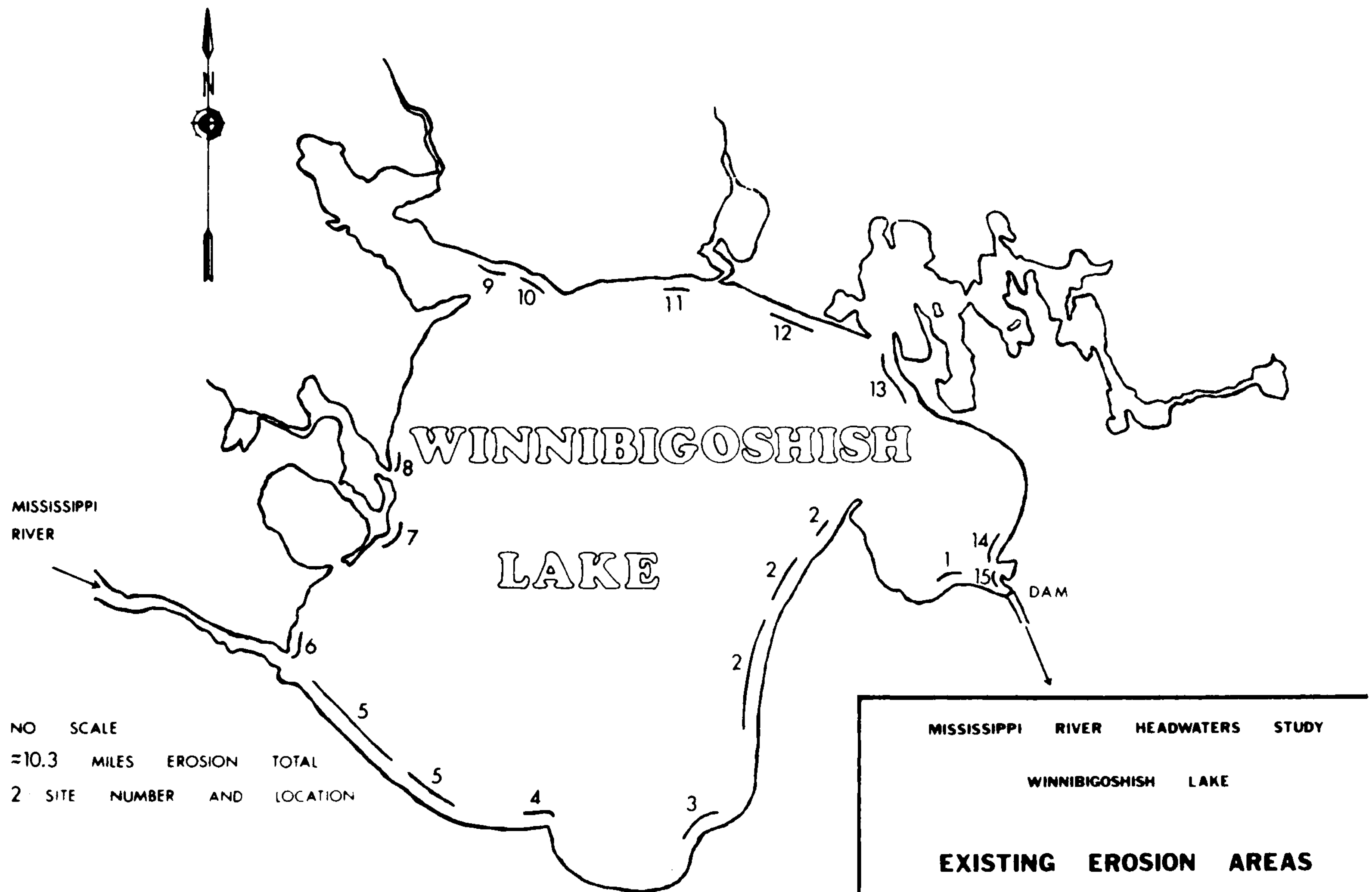
No further evaluation of lake operating plans is recommended at this time. However, further studies are required to evaluate the existing and potential erosion of archeological sites under the existing plan and to evaluate the significance of the sites according to National Register of Historic Places criteria. Measures for bank stabilization and/or data recovery should be developed following these studies. This cultural resources management strategy would be coordinated with the Advisory Council on Historic Preservation, the Minnesota Historic Preservation Officer, the Minnesota Indian Affairs Council, the State Archeologist's office, and property owners. Mitigation would be addressed on a site-by-site basis, depending on the extent and nature of erosion and the suitability of protection and data recovery. This work will have to be scheduled under the District's continuing authority for operation and maintenance of existing projects.

BANK EROSION CONTROL ON SIX MISSISSIPPI HEADWATERS LAKES - PROBLEM 2

Bank erosion is a serious problem on the six Mississippi River Headwaters Lakes. The problem can be divided into two categories: (1) existing and (2) potential. Existing erosion is moderate because of relatively low water levels in the headwaters lakes during the past several years. Potential erosion increases could occur from normal operation during moderate and high-flow years or with any increases in lake operating levels.

Alternative 1: No Action or Base Condition (Present Operating Plan)

Existing conditions of the shoreline around each of the six headwaters lakes were evaluated in a preliminary manner by a boat survey, a previous U.S. Forest Service erosion report, and the 1973 Environmental Review of the six lakes conducted for the St. Paul District by Bemidji State University. The following figures show the locations of existing erosion areas around each lake. The locations were determined by boat surveys conducted by field personnel in 1977.

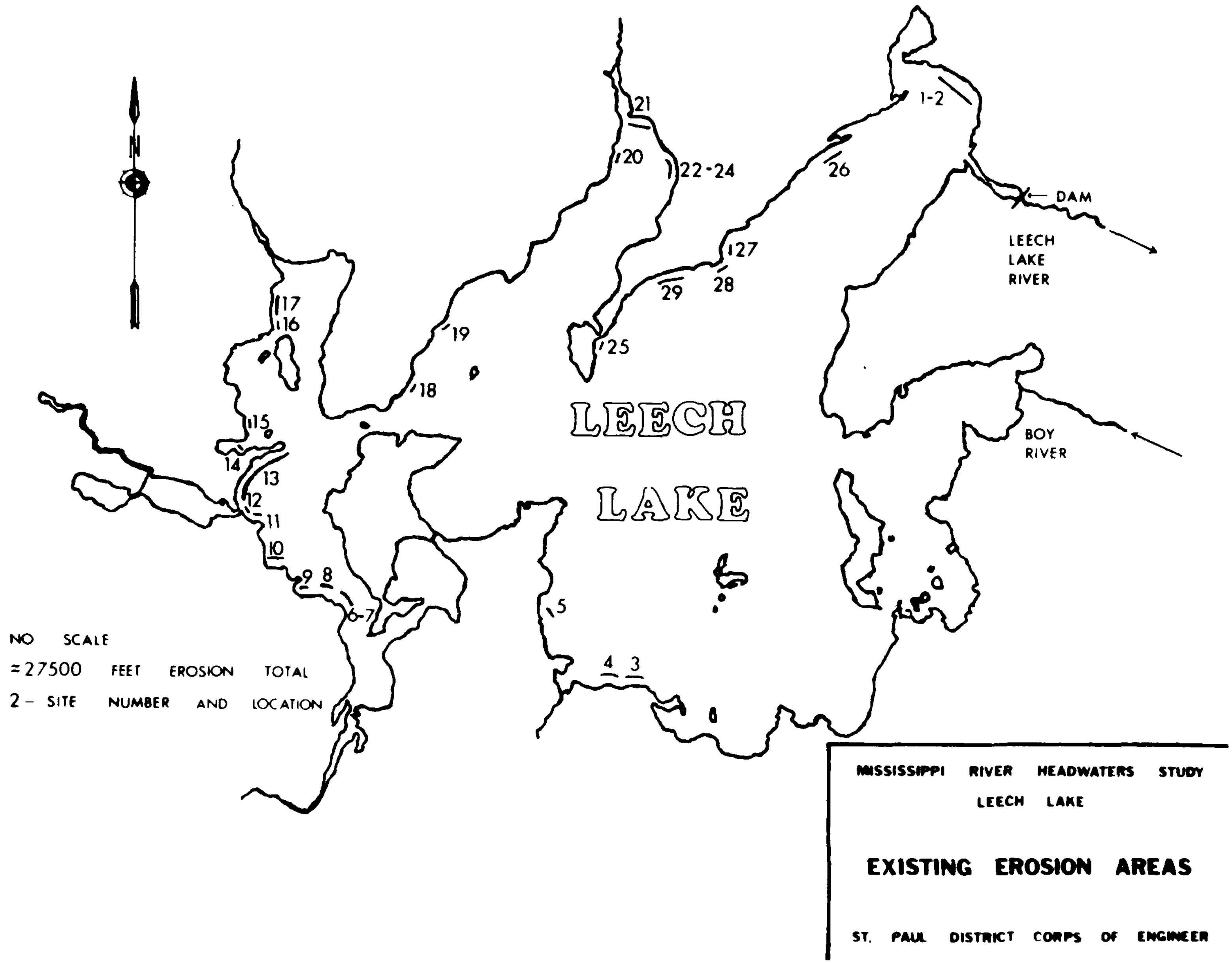


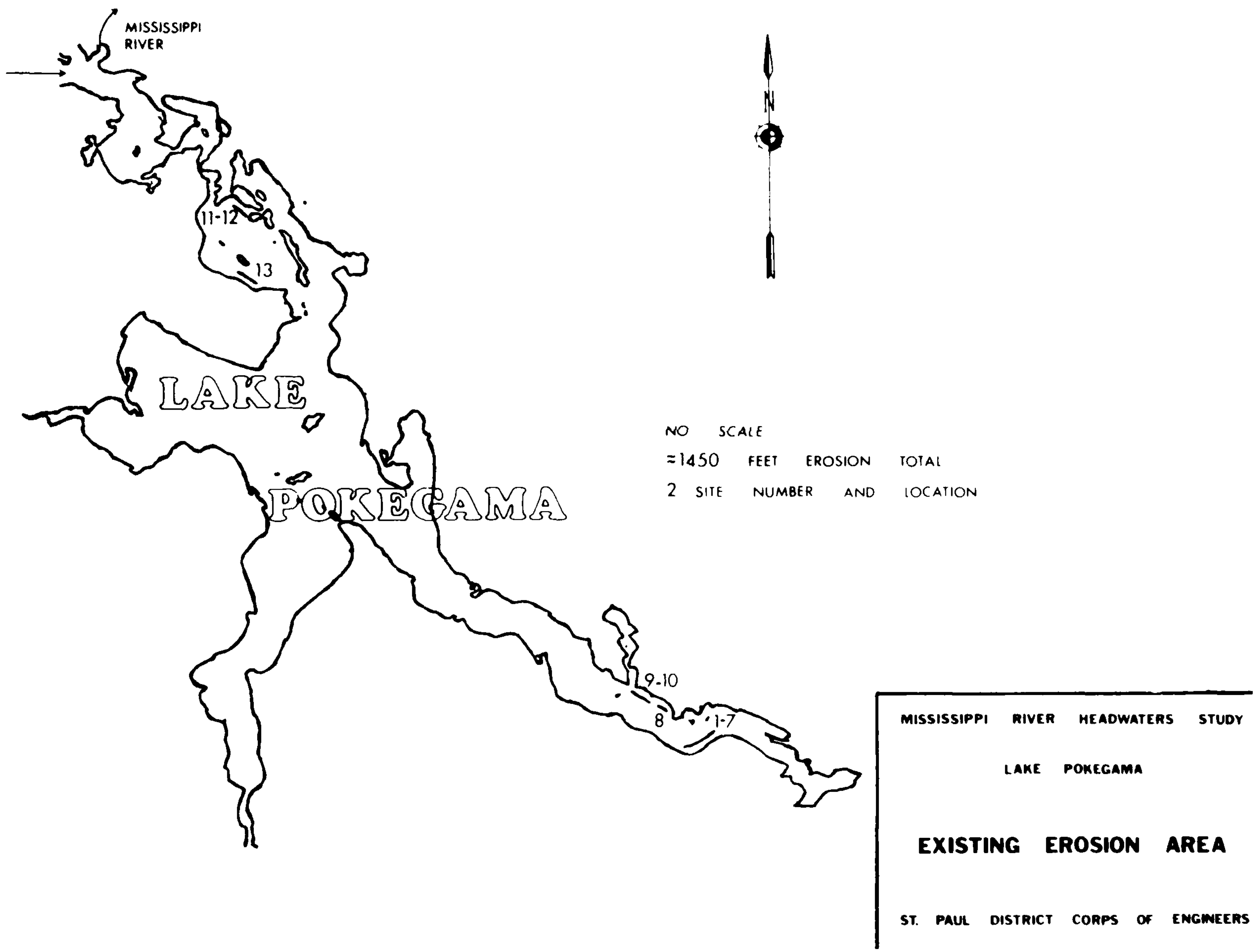
MISSISSIPPI RIVER HEADWATERS STUDY

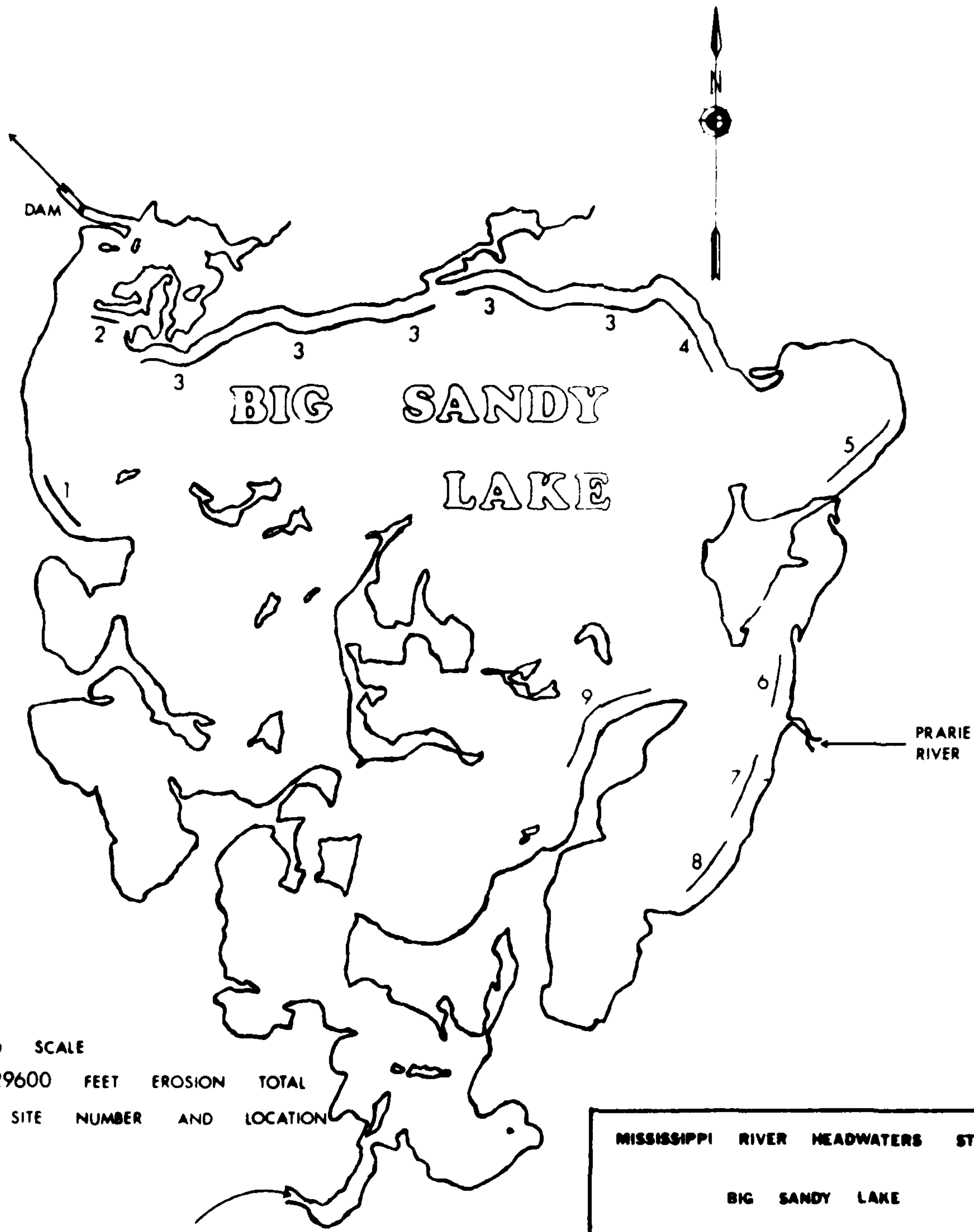
WINNIBIGOSHISH LAKE

EXISTING EROSION AREAS

ST PAUL DISTRICT CORPS OF ENGINEERS


N
LEECH LAKE
LEECH LAKE RIVER
DAM
BOY RIVER
1-2
3
4
5
6-7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22-24
25
26
27
28
29
NO SCALE
≈27500 FEET EROSION TOTAL
2 - SITE NUMBER AND LOCATION
MISSISSIPPI RIVER HEADWATERS STUDY
LEECH LAKE
EXISTING EROSION AREAS
ST. PAUL DISTRICT CORPS OF ENGINEER


MISSISSIPPI RIVER
11-12
13
LAKE POKEGAMA
N
9-10
8
1-7
NO SCALE
≈1450 FEET EROSION TOTAL
2 SITE NUMBER AND LOCATION
MISSISSIPPI RIVER HEADWATERS STUDY
LAKE POKEGAMA
EXISTING EROSION AREA
ST. PAUL DISTRICT CORPS OF ENGINEERS



NO SCALE

≈29600 FEET EROSION TOTAL

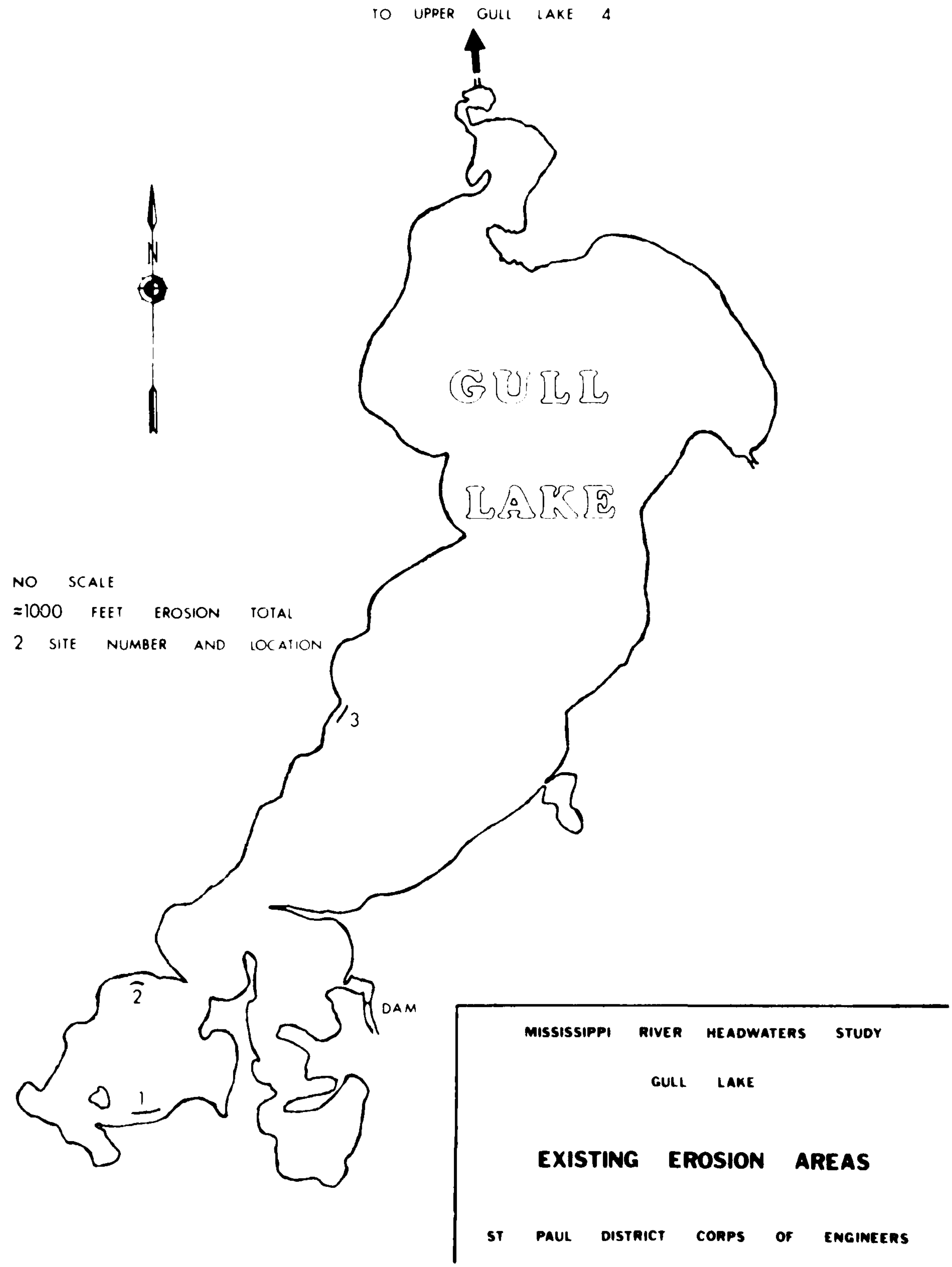
2 SITE NUMBER AND LOCATION

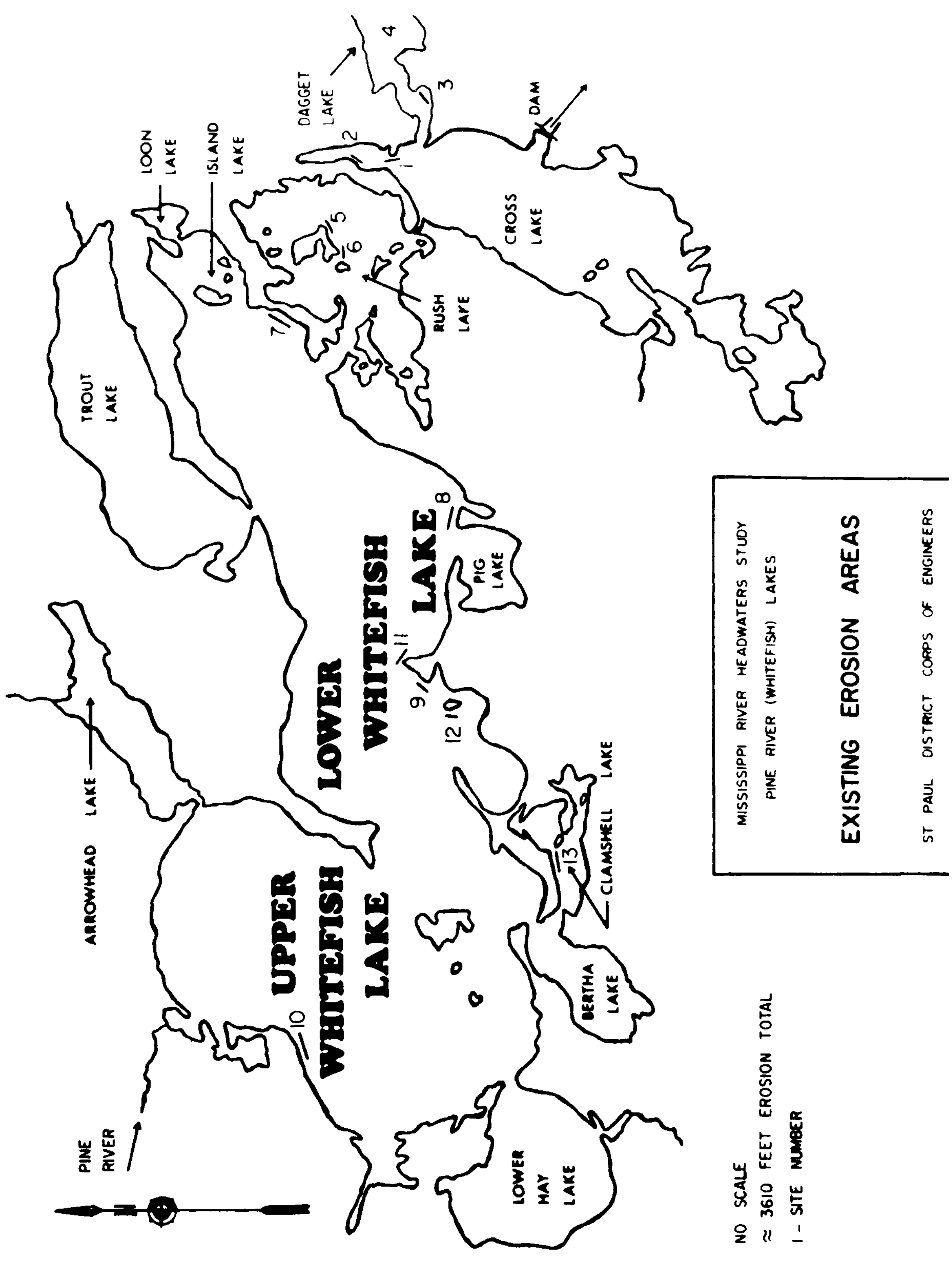
MISSISSIPPI RIVER HEADWATERS STUDY

BIG SANDY LAKE

EXISTING EROSION AREAS

ST. PAUL DISTRICT CORPS OF ENGINEERS


TO UPPER GULL LAKE 4
N
GULL
LAKE
NO SCALE
≈1000 FEET EROSION TOTAL
2 SITE NUMBER AND LOCATION
3
2
1
DAM
MISSISSIPPI RIVER HEADWATERS STUDY
GULL LAKE
EXISTING EROSION AREAS
ST PAUL DISTRICT CORPS OF ENGINEERS


MISSISSIPPI RIVER HEADWATERS STUDY
PINE RIVER (WHITEFISH) LAKES
EXISTING EROSION AREAS
ST PAUL DISTRICT CORPS OF ENGINEERS
NO SCALE
≈ 3610 FEET EROSION TOTAL
1 - SITE NUMBER
PINE RIVER
ARROWHEAD LAKE
UPPER WHITEFISH LAKE
LOWER WHITEFISH LAKE
TROUT LAKE
LOON LAKE
ISLAND LAKE
DAGGET LAKE
DAM
CROSS LAKE
RUSH LAKE
PIG LAKE
CLAMSHELL LAKE
BERTHA LAKE
LOWER HAY LAKE
1
2
3
4
5
6
7
8
9
10
11
12
13

An attempt was made to estimate the current annual cost of existing and potential shoreline erosion. Although no precise figures exist for the number of square feet of shoreline eroded on each of the headwaters lakes, the U.S. Forest Service has made several detailed studies of the losses at Lake Winnibigoshish. These studies indicate that losses vary considerably from one location to another but, at a minimum, losses average about 1 foot of depth per foot of shoreline annually. An estimated dollar value per square foot of property was derived for each of the six headwaters lakes using local assessors' knowledge of recent sales estimates for the value of lakefront property (based on shoreline front footage) and average lot depth. The following table summarizes estimated erosion costs based on an erosion rate of 1 foot of depth per foot of shoreline and on the present length of eroding shoreline.

Estimated erosion costs (1)

Lake	Present shoreline erosion (feet)	Value per front square foot	Annual value of lost shoreline
Winnibigoshish	54,250	$0.11	$5,950
Leech	27,500	0.27	7,400
Pokegama	1,450	0.58	850
Sandy	29,600	0.54	16,000
Pine River	3,610	0.84	3,050
Gull	1,000	0.87	850
Total	117,410		34,100

(1) October 1977 cost indexed to October 1981 prices.

The following table compares present lakeshore erosion under the existing plan of lake operation with two potential erosion situations with a lake operating plan using higher water levels.

Existing and potential erosion

Lake	Total shoreline (1) Miles	Total shoreline (1) Feet	Present erosion (feet)	Potential erosion (2) To developed properties (feet)	Potential erosion (2) To all shoreline properties (feet)
Winnibigoshish	35.0	184,800	54,250	79,200	114,800
Leech	182.3	962,550	27,500	34,000	808,550
Pokegama	50.8	268,200	1,450	55,100	147,600
Sandy	56.5	298,300	29,600	42,100	293,000
Pine River	106.0	559,680	3,610	112,000	498,700
Gull	35.6	188,000	1,000	100,000	170,000
Total	466.2	2,461,530	117,410	422,400	2,032,650

(1) Figures are for the lake proper and are from the 1967 Minnesota Department of Natural Resources Shoreline Management Study.

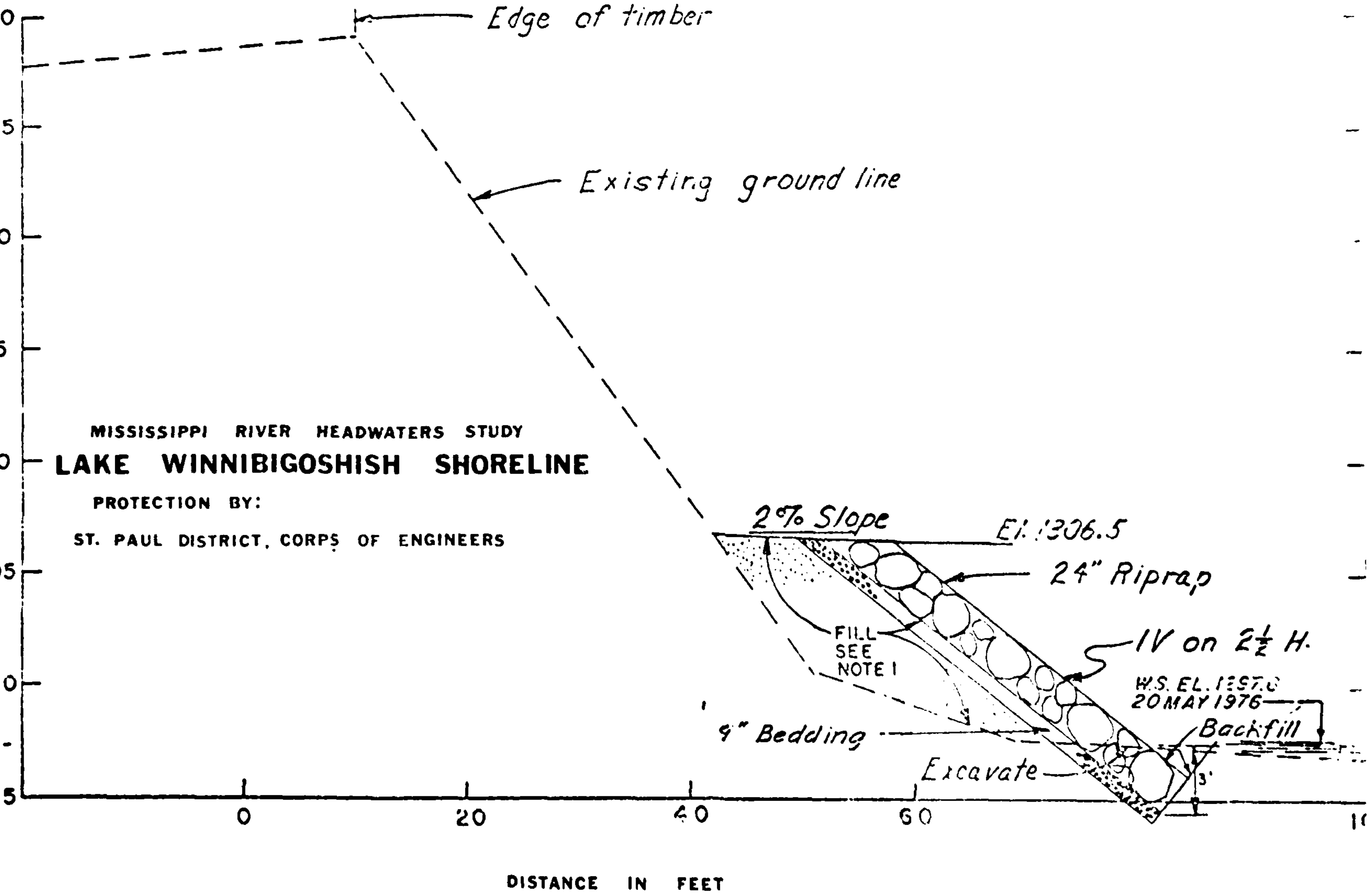
(2) Potential erosion values also include the present or existing erosion values shown.

Existing erosion estimates for the six headwaters lakes were obtained through observations taken by boat. Figures for potential erosion to developed properties were derived from flood damage surveys on Sandy and Pokegama Lakes and from erosion surveys taken by the U.S. Forest Service on Lake Winnibigoshish. Potential erosion values for developed properties on the remaining three lakes (Leech, Pine River, and Gull) were derived using correlations with the three surveyed lakes. Potential shoreline erosion to all areas for each of the six lakes was assumed to include all properties that had onshore slopes greater than 5 percent.

An economic and hydraulic study of the effects of individual lake operating plans is currently in progress. The effects of lake operating plans on erosion around each lake will be evaluated during this study.

Alternative 2: Riprap Bank Protection

This alternative involves protection of potential erosion properties around each lake with graded fill and 24 inches of riprap. The St. Paul District is currently using this method to protect the headquarters property on Lake Winnibigoshish. The protection would be provided only for developed properties. The riprap would be placed on a 2.5:1 slope extending from near the normal summer operating level to 3 feet above the 100-year level for maximum observed water levels on each lake. In situations where the property or developments were at an elevation less than the desired protection level described above, the riprap would be carried only to the maximum elevation of the property. The final design for locations around the lake would require more investigation and engineering study. A typical riprap installation for Lake Winnibigoshish, for estimate purposes, is shown on the following figure.


MISSISSIPPI RIVER HEADWATERS STUDY
LAKE WINNIBIGOSHISH SHORELINE
PROTECTION BY:
ST. PAUL DISTRICT, CORPS OF ENGINEERS
Edge of timber
Existing ground line
2% Slope
El. 1306.5
24" Riprap
1V on 2½ H.
FILL SEE NOTE 1
9" Bedding
Excavate
Backfill
W.S. EL. 1297.0 20 MAY 1976
3'
ELEVATION
1330
1325
1320
1315
1310
1305
1300
1295
0
20
40
60
DISTANCE IN FEET

The total first cost of protecting headwaters lakes property from erosion in this manner would be $16,280,000. The benefit-cost ratio for this alternative is 0.20. Cost elements for the six lakes are shown in the following table.

Alternative 2 - summary of riprap protection costs - six headwaters lakes

Lake	Potential damage area requiring protection (feet) (1)	Protection first cost	Protection annual cost (2)	Annual value of shore-line lost (per foot)	Total annual value of lost shoreline
Winnibigoshish	79,200	$3,323,000	$253.500	$0.11	$8,700
Leech	34,000	1,130,000	86,200	0.27	9,200
Pokegama	55,100	2,419,000	184,600	0.58	32,000
Sandy	42,100	1,853,000	141,400	0.54	22,700
Pine River	112,000	4,919,000	375,300	0.84	94,100
Gull	100,000	2,636,000	201,100	0.87	87,000
Total	422,400	16,280,000	1,242,100		253,700

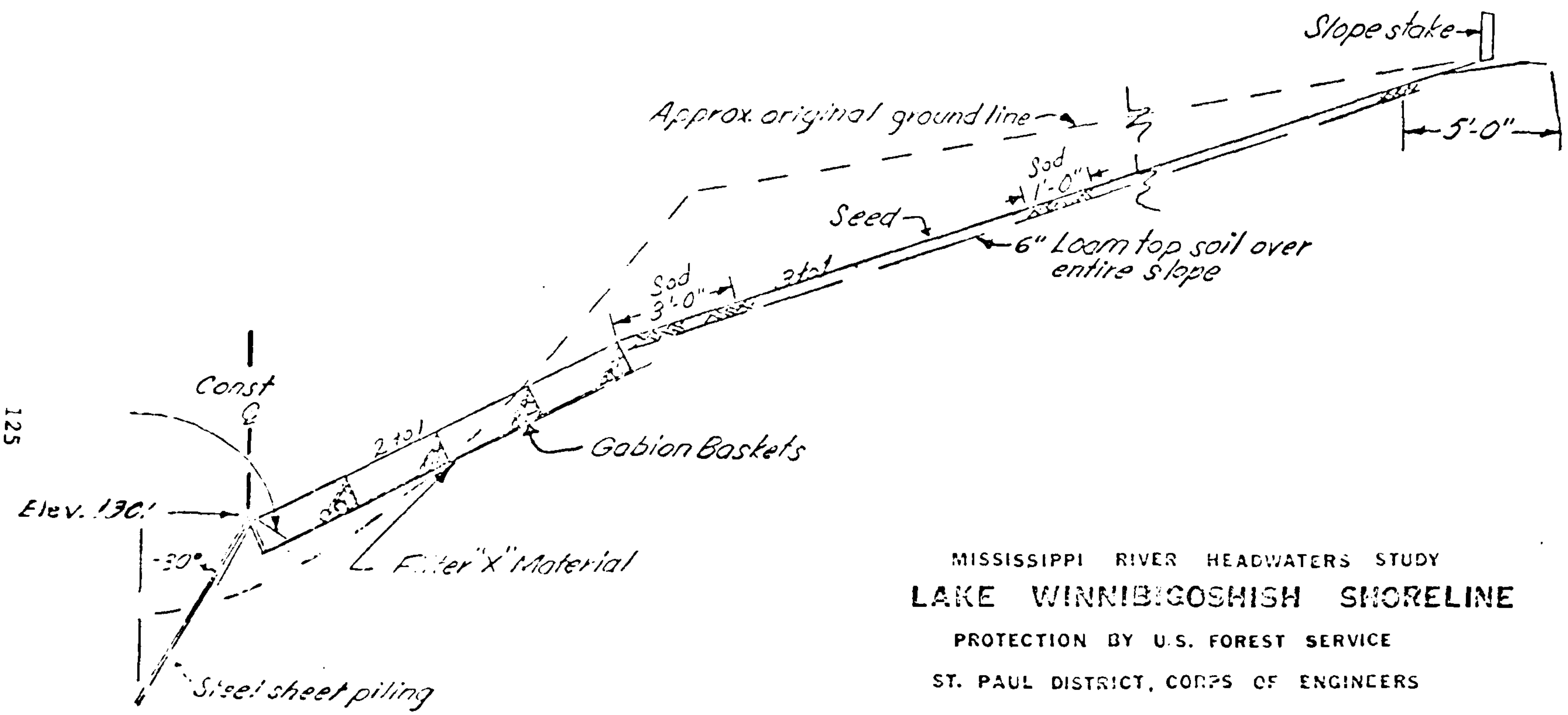
Benefit-cost ratio $= \frac{\$253,700}{\$1,242,100} = 0.20$

(1) Derived from 1965 U.S. Forest Service Shoreline Survey and 1977 St. Paul District damage surveys; includes only developed or potentially developable properties.
(2) Based on 100-year project life and 7 5/8-percent interest rate (no operation and maintenance costs).

Alternative 3: Riprap and Gabion Bank Protection

This alternative involves protection of potential erosion properties with a combination of steel sheet-piling and gabions. As in alternative 2, protection would be provided only for developed properties. In this method, steel sheet-piling is driven into the toe of the shoreline slope at a 30^{o} angle. Rock-filled wire baskets (gabions) are placed on a 2:1 slope behind the sheet-piling. The limits of protection are the same as those in alternative 2.

This method of protection has been used by the U.S. Forest Service on Lake Winnibigoshish. The Forest Service does not recommend this method for additional work on the lakes because it has experienced considerable difficulty with keeping the sheet-piling in place. Also, this method is more costly than alternative 2. A typical alternative 3 shoreline protection installation for Lake Winnibigoshish is shown on the following figure.



MISSISSIPPI RIVER HEADWATERS STUDY

LAKE WINNIBIGOSHISH SHORELINE

PROTECTION BY U.S. FOREST SERVICE

ST. PAUL DISTRICT, CORPS OF ENGINEERS

Typical Slope Section
No Scale

The total first cost for this alternative is $29,628,000. The benefit-cost ratio is 0.11. Costs for each of the lakes are shown in the following table.

Alternative 3 - summary of riprap and gabion protection costs - six headwaters lakes

Lake	Potential damage and required protection (1) (feet)	Protection first cost	Protection annual (2) cost	Annual value of shore-line lost (per foot)	Total annual value of lost shoreline
Winnibigoshish	79,200	$6,047,000	$461,400	$0.11	$8,700
Leech	34,000	2,056,000	156,900	0.27	9,200
Pokegama	55,100	4,402,000	335,900	0.58	31,950
Sandy	42,100	3,373,000	257,400	0.54	22,750
Pine River	112,000	8,953,000	683,100	0.84	94,100
Gull	100,000	4,797,000	366,000	0.87	87,000
Total	422,400	29,628,000	2,260,700		253,700

$$\text{Benefit-cost ratio} = \frac{\$253,700}{2,260,700} = 0.11$$

(1) Derived from 1965 U.S. Forest Service Shoreline Survey and from 1977 St. Paul District damage surveys. Includes only developed or potentially developable properties.
(2) Based on 100-year project life and 7 5/8-percent interest rate (no operation and maintenance costs).

Alternative 4: Natural Beach Protection

This alternative involves placing ungraded gravel on shoreline slopes that are generally less than 10 percent slope. The method is currently being used by the U.S. Forest Service on four Lake Winnibigoshish campground areas on an experimental basis and seems to be doing well. During the winter, approximately 1 cubic yard of ungraded gravel, up to 6 inches in diameter, is brought in over the ice and placed on each 1 foot width of eroding shoreline. The cost of this work is about $8 per foot of shoreline.

The total first cost of protecting potentially erodible headwaters lakes shoreline in this manner would be $4,528,100. The benefit-cost ratio for this alternative is 0.73 assuming no operation and maintenance costs are included and the project has a 100-year life. Costs for each of the lakes are shown in the following table.

Alternative 4 - natural method of shoreline protection

Lake	Potential damage area requiring protection (feet)(1)	Protection first cost(2)	Protection annual cost(3)	Annual value of shoreline lost (per foot)	Total annual value of lost shoreline
Winnibigoshish	79,200	$849,000	$64,800	$0.11	$8,700
Leech	34,000	364,500	27,800	0.27	9,200
Pokegama	55,100	590,700	45,100	0.58	31,950
Sandy	42,100	451,300	34,400	0.54	22,750
Pine River	112,000	1,200,600	91,600	0.84	94,100
Gull	100,000	1,072,000	81,800	0.87	87,000
Total	422,400	4,528,100	345,500		253,700

$$\text{Benefit-cost ratio} = \frac{\$253,700}{345,500} = 0.73$$

(1) Derived from 1965 U.S. Forest Service Shoreline Survey and 1977 St. Paul District damage surveys. Includes only developed or potentially developable properties.
(2) $8 per foot of shoreline (1977 prices) indexed to October 1981 prices.
(3) Based on 100-year project life and 7 5/8-percent interest rate.

Review of Alternatives

The following table summarizes the economic factors of the four erosion control alternatives.

Economic factors of the four erosion control alternatives

Item	First cost	Annual cost(2)	Annual benefit	Benefit-cost ratio
Alternative 1				
Base condition (present operating plan)	-	$34,100	-	-
Revised operating plans:				
a. Natural conditions	-	Considerably less than 34,100	-	-
b. Flood control	-	34,100 or less	-	-
c. Low flow	-	34,100 or less	-	-
Alternative 2(1)				
Riprap bank protection	$16,280,000	1,242,000	$253,600	0.20
Alternative 3(1)				
Riprap and gabion bank protection	29,627,000	2,661,000	253,600	0.10
Alternative 4(1)				
Natural beach protection	4,528,000	345,500	253,600	0.73

(1) Protection for developed lake properties only.
(2) No operation and maintenance costs.

Cultural Resources

Erosion problems at all of the headwaters lakes are having a negative effect on cultural resources. Sites are eroding at an alarming rate and much significant data is being lost every year. Under the present operating plan, much of the severe erosion has been stabilized in some areas. Changes to the operating plan could increase erosion problems and thus increase impacts on sites. Any action taken to reduce shoreline erosion could have a beneficial effect on sites.

Future study needs include additional surveys to locate all sites along the shores of the various lakes that may be eroding, testing these sites to determine their eligibility for the National Register, and mitigating those sites found to be listed on or eligible for inclusion on the National Register. These studies will be conducted under the District's operation and maintenance authority.

Recommendations

The evaluation indicates the two structural protection alternatives are not economically feasible. Since the benefit-cost ratio is so low, any shoreline erosion reduction measures will have to be considered only on a case by case basis and not as part of a major shoreline erosion control program. Existing and potential erosion at individual archeological sites will be addressed further under the District's operation and maintenance authority. Environmental assessments would be conducted under the same authority to determine potential impacts on the natural and human environment.

EROSION PROBLEMS DOWNSTREAM OF POKEGAMA DAM - PROBLEM 3

This problem was identified by a local citizen at a study area workshop. The situation involves changes in the Mississippi River channel about 10 miles downstream from the Pokegama Dam, near the town of Blackberry. According to the landowner, the problem took on damaging proportions in 1962 when the first of three threatened oxbows used for pasture was cut off by a newly formed channel. At present, one 40-acre and one 2-acre loop have been cut off and a 40-acre loop is threatened.

Alternative 1: No Action

Erosion and channel changes are common in the entire 140-mile section of the Mississippi River from the mouth of the Prairie River downstream from Grand Rapids to below Aitkin. Much of this area was once a part of glacial Lake Aitkin and consequently the river valley is quite flat with numerous meanders and channel changes.

The land containing the affected oxbows is woody lowland currently being used for pasture. At an estimated value of $28 per acre for pasturage, the present annual loss of productive land in the Blackberry area of about $1,100 is expected to continue at the same rate.

Alternative 2: Revise Pokegama Lake Operation

This alternative is being evaluated in the current Mississippi River Headwaters computer analysis of reservoir operation. However, a review of natural outflow versus regulated outflow from Pokegama Dam for high water years 1962, 1966, and 1969 indicates that the Pokegama Dam generally reduces peak stages and discharges in the Blackberry area. This is particularly true for low or moderate spring runoff periods.

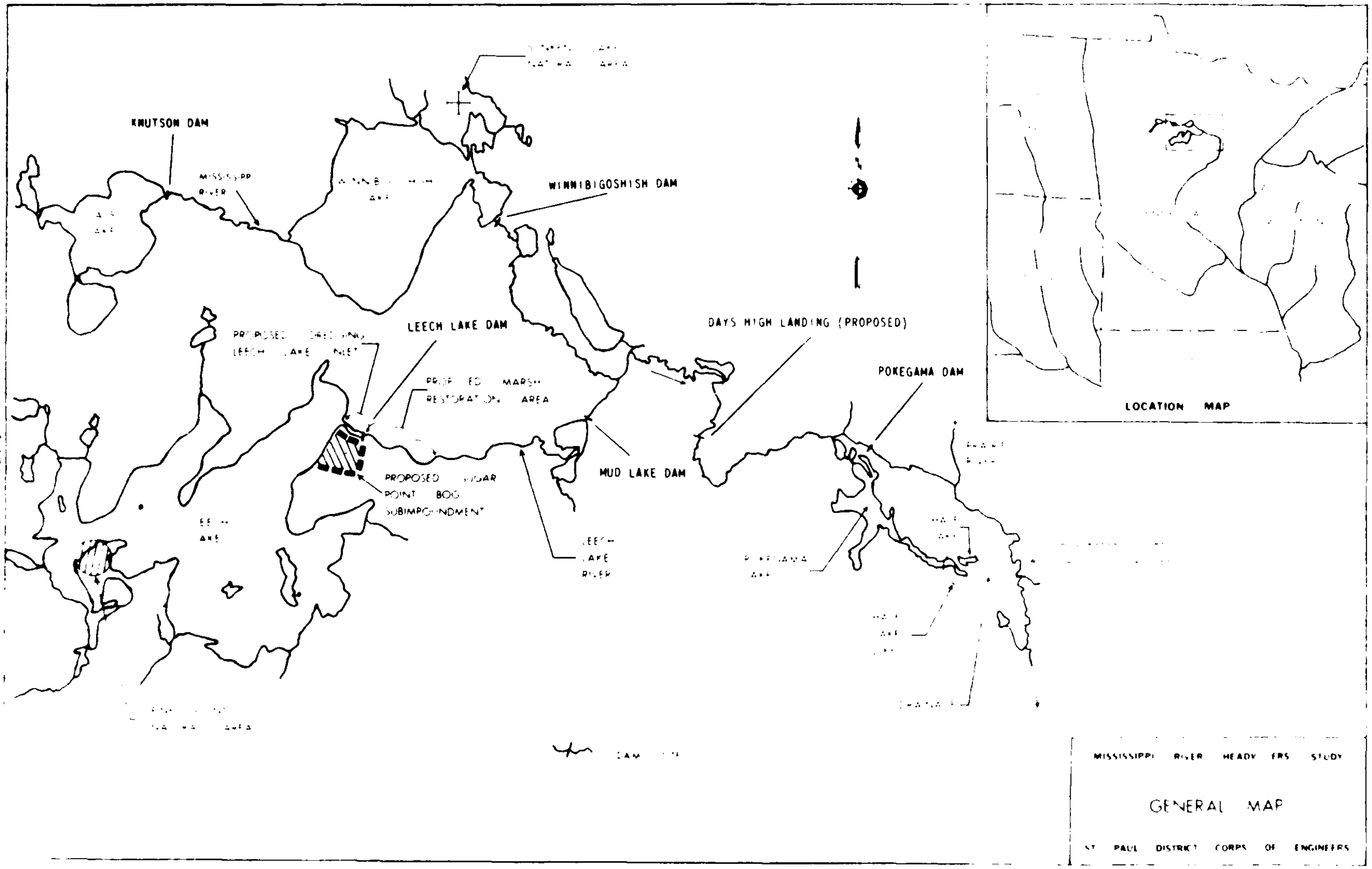
Within present operating limits, Pokegama Lake has less than one-sixth of the storage capacity of Winnibigoshish and Leech Lakes which are located farther upstream. Consequently, much of the inflow that enters the lake must be passed along. The hydrographs of natural outflow versus regulated outflow for 1962, 1966, and 1969 confirm this fact. Natural flood outflows from Pokegama Lake vary from regulated outflows in timing rather than in magnitude, although the lake is effective in reducing the outflows from lesser floods.

Alternative 3: Remove Hale Lake Dikes

In the early 1900's, three dikes were constructed on the east end of Pokegama Lake to prevent high water levels from bypassing Pokegama Dam and overflowing into natural watercourses. Evaluation of information available on these dikes indicates that water would have had to exceed elevation 1273.42 (9.0-foot stage) in Pokegama Lake before it could have started flowing through the old natural channels that are now diked off.

The water that would have flowed out through the natural channels would reenter the Mississippi River downstream of the Blackberry area having the erosion problems. The local people believe that removing the Hale Lake dikes would help solve their erosion problem. However, data on file indicate that Pokegama Lake would have been discharging 3,400 cfs or more at Grand Rapids at that elevation of overflow. The Mississippi River lowlands in question would already be flooded from this flow and would be further inundated by runoff from the Prairie River which has a 530-square mile drainage area.

This alternative was not considered further because the Hale Lake dikes are presently a part of the county road system and removing the dikes would not benefit the Blackberry erosion area. The general Hale Lake dike system location is shown in relation to other study area features in the following figure.


KNUTSON DAM
WINNIBIGOSHISH DAM
LEECH LAKE DAM
PROPOSED DREDGING
LEECH LAKE INLET
PROPOSED MARSH
RESTORATION AREA
PROPOSED SUGAR
POINT BOG
SUBIMPOUNDMENT
MUD LAKE DAM
LEECH
LAKE
RIVER
DAYS HIGH LANDING (PROPOSED)
POKEGAMA DAM
LOCATION MAP
MISSISSIPPI RIVER HEADWATERS STUDY
GENERAL MAP
ST PAUL DISTRICT CORPS OF ENGINEERS

Alternative 4: Restoration and Protection of Oxbows

This alternative considers the feasibility of reconnecting the cut-off 40-acre oxbow area to the left riverbank. This alternative would also protect another threatened 40-acre oxbow just upstream from the one presently cut off. No attempt would be made to reconnect the small, 2-acre oxbow because of its relative insignificance.

The cut-off oxbow would be connected to the left bank with compacted fill and riprap on both the upstream and downstream face. The endangered oxbow would be strengthened with a small levee on the upstream side to prevent water from cutting across the oxbow during high water periods. The levee would have riprap only on the upstream face. In both instances, the land would be submerged during floods but would not provide an overland route for flood flows. The proposed levees are shown in the figure on page 71. This alternative is not economically feasible. The first costs of restoring the oxbow and protecting the existing oxbow are $24,750 and $19,250, respectively. The respective benefit-cost ratios are 0.37 amd 0.48.

Review of Alternatives

Cost data for the structural and nonstructural alternatives are summarized in the following table. No environmental assessment was made for this problem because no feasible solutions are available. Meander formation is a natural process.

Erosion problems downstream of Pokegama Dam - summary of cost data for alternatives

Alternative	First cost	Annual cost (1)	Annual benefit	Benefit-cost ratio
1. No action	-	$1,100	-	-
2. Revise Pokegama Lake operation	-------- Not an effective solution ----------			
3. Remove Hale Lake Dam	-------- Not an effective solution ----------			
4. Restore and protect oxbows:				
a. Levee to save threatened 40 acres	$19,250	2,290	$1,100	0.48
b. Levee to restore 40 acres lost	24,750	2,900	1,100	0.38

(1) Includes operation and maintenance costs.

Cultural Resources

The natural process of oxbow formation has a direct impact on cultural resources. However, because this is a natural process and there are no feasible solutions, it is not within the current jurisdiction of the Corps to mitigate these impacts.

Recommendations

Since no economically feasible improvements are available to control the problem, the no action alternative is recommended and no further studies are recommended.

WHITE OAK LAKE WATER LEVELS - PROBLEM 4

The White Oak Lake area presently consists of about 7,500 acres of open marsh area through which the Mississippi River flows between Winnibigoshish and Pokegama Lakes. The area lies completely within the established U.S. Government flowage limits for Pokegama Lake and extends 11 miles downstream from the confluence of the Leech Lake and Mississippi Rivers to a narrow valley constriction known as Days High Landing. The overall area involved in the Pokegama flowage is known locally as the "Great Meadow" and is over 20,000 acres in size.

The detrimental effects of fluctuating water levels in the "Great Meadow" area on wild rice, fish, and wildlife have been the concern of both local people and government officials since the early 1900's. Stabilization of water levels in the White Oak Lake area would recover some of the damages to wildlife, fisheries, and wild rice that resulted from channel straightening between Winnibigoshish Dam and Pokegama Lake from 1914 to 1926. This work was accomplished by the Corps of Engineers to improve Winnibigoshish flows to Pokegama Lake and to improve downstream navigation below Minneapolis.

Alternative 1: No Action

At present, no rural or urban damages result from the fluctuating water levels in the White Oake Lake area. However, losses to fish, wildlife, and wild rice and low water inconvenience to boaters, sportsmen, and residents of the town of Deer River do occur. Specific damages would continue with a do nothing approach: (2) late winter drawdowns of Pokegama Lake can result in winter fish and muskrat kills, (b) low water in the spring with subsequent summer floods can adversely affect nesting waterfowl, and (c) summer fluctuations of water levels due to flood runoff adversely affect wild rice growing in the area.

Currently the White Oak Lake area is included in a reach of the Mississippi River being considered for a "Scenic River" designation under the Wild and Scenic Rivers Act of 1968. If so designated, this reach of river would remain in its present undeveloped state.

Alternative 2: Control Dam

This alternative would consist of constructing a dam to raise and stabilize water levels in approximately 17 miles of the Mississippi River from Days High Landing to a point several miles downstream of the junction of the Mississippi and Leech Lake Rivers. The dam would impound about 6,300 water surface acres at elevation 1278.5, the normal pool level.

The dam at Days High Landing would have no flood control storage capacity other than that already provided by Pokegama Dam. The dam would stabilize water levels in the White Oak and Little White Oak Lakes vicinity during periods of normal and low flows and for low stages in Pokegama Lake. During periods of high flow, the dam would be open and would drain out, with control reverting to Pokegama Dam.

The dam as originally proposed would be a concrete control structure with six stop log bays and one sluice gate bay. The dam would also have earth tieback levees with a maximum height of about 19 feet. No navigation lock would be included in this alternative, only a canoe and small-boat portage around the dam. The first cost of such a dam would be $2,894,000; it would have a favorable benefit-cost ratio of 1.71. The site of the proposed dam is shown in the figure on page 68.

Alternative 3: Dam and Concrete Navigation Lock

Alternative 3 would include construction of the dam as described in alternative 2 plus a navigation lock for recreation boat traffic. Considerable interest in a lock was expressed at the 5 November 1969 public meeting on a proposed dam at the Days High Landing site.

Construction of a permanent 25- by 80-foot concrete lock with related appurtenances could more than double the cost of alternative 2 with no appreciable increase in benefits. Increased benefits would have to result from increased recreation use. Including a permanent lock and related facilities would add approximately $4.7 million to the total construction cost. The first cost of a dam and concrete navigation lock would be $7,584,000. The project would have an unfavorable benefit-cost ratio of 0.61.

Alternative 4: Dam and Mobile Boat Carrier

Alternative 4 would consist of constructing the dam as described in alternative 2 and including a mobile boat carrier to portage recreational boat traffic. The mobile boat carrier would be able to transport a recreational craft up to 38 feet long, 12 feet wide, and having a draft of 3.5 feet.

The transporting device would use either a sling or tank arrangement. If a tank arrangement were used, the transported boat would be anchored by means of floating mooring bits. The added first cost of this type of lockage facility would be $775,000; the total first cost with the dam would be $3,672,000. This alternative would have a less than favorable benefit-cost ratio of 0.99.

Alternative 5: Leech Lake Subimpoundments

This alternative was investigated at the request of the Minnesota Department of Natural Resources. The principal objective of this alternative would be to provide fish and wildlife benefits in an alternate location to offset the fish, wildlife, and wild rice damages experienced in the White Oak-Little White Oak Lakes area of the Pokegama Lake flowage.

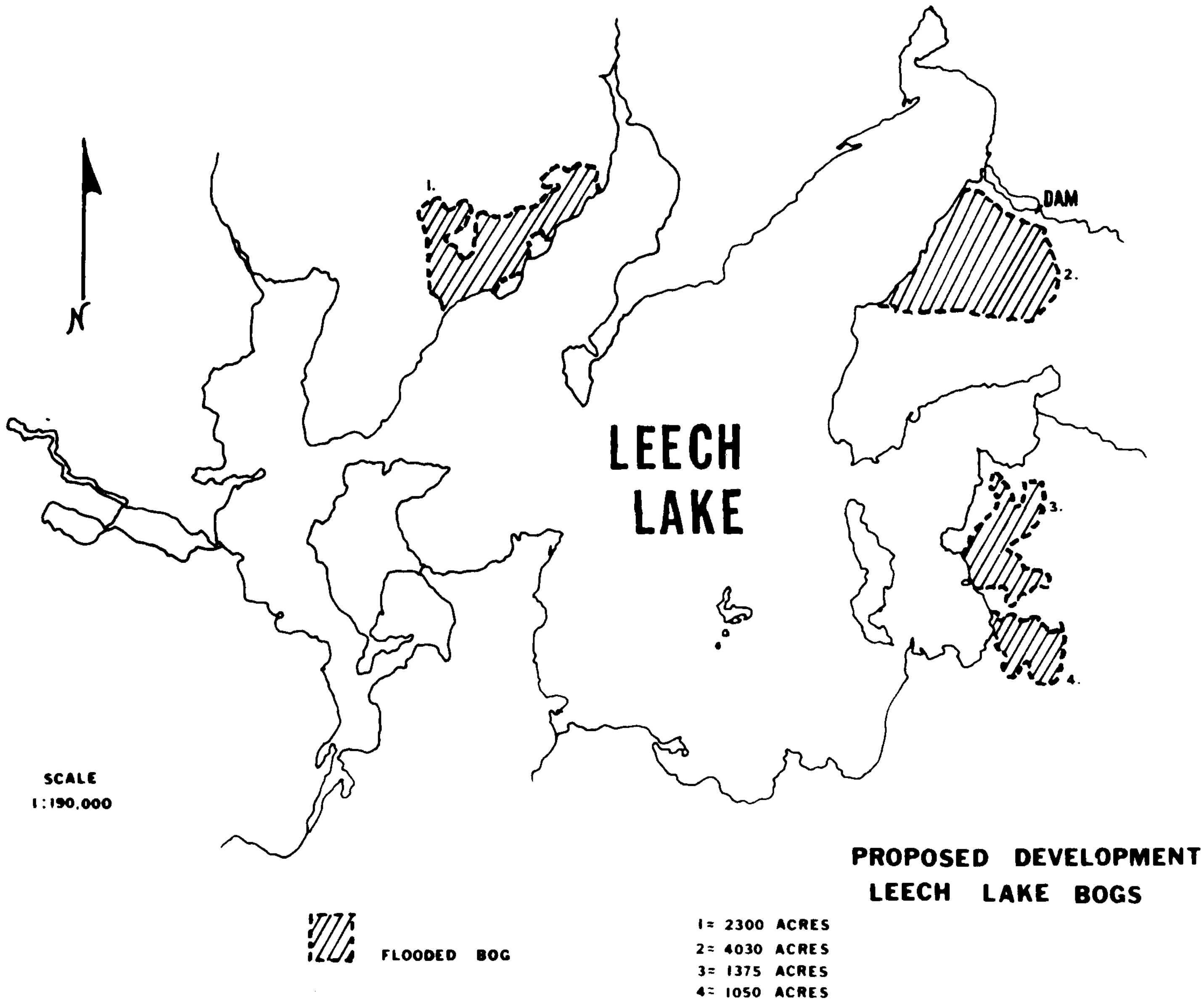
Four separate marsh or bog areas on Leech Lake were considered for subdiking with 18 to 24 inches of water for increased wild rice production and for increased northern pike spawning habitat. None of the four areas is economically feasible because each would require a pumping station to maintain the required stable water levels and a control structure for drawdown. The areas under consideration and their cost data are summarized in the following table.

Leech Lake subimpoundments - costs and benefits

Site	Bog name	Acquisition area (acres)	Developed area (acres)	First cost	Annual cost[(1)]	Annual benefit	Benefit cost ratio
1	Bowstring	2,300	629	$1,465,000	$175,400	$47,000	0.26
2	Sugar Point	4,030	2,800	2,002,800	252,100	210,000	0.83
3	Boy Lake	1,375	1,049	922,300	111,100	78,500	0.70
4	Boy Lake	1,050	574	700,700	93,500	43,000	0.46

(1) Includes operation and maintenance costs.

Alternative 5 is illustrated on the following figure.



N
1.
DAM
2.
3.
4.
LEECH
LAKE
SCALE
1:190,000
PROPOSED DEVELOPMENT
LEECH LAKE BOGS
FLOODED BOG
1= 2300 ACRES
2= 4030 ACRES
3= 1375 ACRES
4= 1050 ACRES

Review of Alternatives

Cost data for the alternatives are summarized in the following table.

White Oak Lake water level alternatives for fish, wildlife, and wild rice benefits

Alternative	First cost	Annual cost (1)	Annual benefit	Benefit-cost ratio
1. No action	-	-	-	-
2. Control dam	$2,89[illegible],000	[illegible]	$425,000	[illegible]
3. Control dam and concrete lock	[illegible]	[illegible]93,000	[illegible]	[illegible]
4. Control dam and mobile lock	[illegible],672,000	[illegible],700	[illegible]	[illegible]
5. Leech Lake subimpoundments				
a. Bowstring	1,465,000	175,400	47,000	0.26
b. Sugar Point	2,002,000	252,100	210,000	0.83
c. Boy Lake	922,300	111,100	78,500	0.70
d. Boy Lake	700,700	93,500	43,000	0.46

(1) Includes operation and maintenance costs.

Alternatives Considered Further

Alternatives 1, 2, and 4 were considered further. Alternative 1 (no action) in the absence of economic feasibility or acceptability remains a logical alternative. Alternatives 2 and 4 show economic feasibility.

Contribution of Alternatives to Specific Planning Objectives

The following table ranks the alternatives according to their contributions to specific planning objectives. Alternative 4 ranks highest in regard to specific planning objectives, and alternative 2 ranks second.

Rating of alternatives

Specific planning objectives	Plan satisfaction rating High		Low
Economic feasibility	Alternative 2	Alternative 4	Alternative 1
Preserve and enhance the quality of the present area environment	Alternative 1	Alternative 4	Alternative 2
Enhance economic welfare of the basin population	Alternative 4	Alternative 2	Alternative 1
Minimum disruption to man-made or natural resources	Alternative 1	Alternative 4	Alternative 2
Social acceptability	Alternative 4	Alternative 2	Alternative 1
Local cooperation	Alternative 4	Alternative 2	Alternative 1

Alternative 1: No action. (This alternative includes designation of Mississippi River segments under the Wild and Scenic Rivers system.)
Alternative 2: Control dam.
Alternative 4: Control dam and mobile lock.

Contribution of Alternatives to National Objectives

The contribution made by each alternative to the two national objectives of economic development and environmental quality must be evaluated. The Principles and Standards require that a national economic development plan and an environmental quality plan be identified. Normally a nonstructural plan is also identified; in this case, no nonstructural plan could be identified.

The national economic development plan is that plan which maximizes net economic benefits while addressing the range of planning objectives. National economic benefits are determined by measuring and analyzing the net value of increases in goods and services derived from the plan. The national economic development plan is alternative 2.

An environmental quality plan would provide a net benefit or net increase in environmental quality through preservation, restoration, or enhancement of environmental quality. No such plan could be designated for White Oak Lake. Although production of wildfowl, fish and wildlife might increase with stabilized water levels, it would not offset the loss of natural wetland and riverine habitat that would result from implementation of this alternative.

Effects of alternatives [illegible]

Environmental quality item	Alternative [illegible] No action	Alternative [illegible] Control [illegible]	[illegible]
Wild and scenic rivers	0 - No change.	-2 - Significant eff[illegible] segment of river cur- rently proposed for scenic designation.	- [illegible]
Natural streams	0 - No change.	-2 - Major reducti[illegible] stream habitat.	[illegible]
Beaches	0 - No change.	0 - No known effect.	- Same as [illegible]
Archeological/historical	0 - No change.	-2 - Would affect archeological and historical [illegible] White Oak Point.	- - [illegible]
Social	0 - No change.	0 - No known effect.	- Same as [illegible]
Aesthetic values	0 - No change.	-1 - Unsightly conditions during construction.	-[illegible] - [illegible]
Open space	0 - No change.	0 - No change.	- Same as [illegible]
Land quality	0 - No change.	-1 - Essentially no change as [illegible] area has much marsh and open water already.	[illegible]
Recreation	0 - No change.	+1 - Increase in hunting, trapping, fishing, and canoeing opportunities.	+[illegible] - Same as [illegible] [illegible]
Air quality and noise	0 - No change.	-1 - Minor and short-term pollution caused by construction.	-1 - Same as [illegible]
Streambank erosion	0 - No change.	-1 - Some erosion expected.	-1 - Same as [illegible]
Water quality	0 - No change.	-1 - Some initial decrease in water quality during construction. Some possible with changed ecosystem.	-1 - Same as [illegible]
Biological resources	0 - No change.	+2 - Significant increase [illegible] productivity.	+2 - Same as [illegible]
Rare and endangered	0 - No change.	0 No known effect.	[illegible] Same as [illegible]
Ecological systems: Terrestrial	0 - No change.	-1 - Some loss of land [illegible] higher pool levels.	[illegible]
Aquatic	0 - No change.	-2 - Significant loss [illegible]	[illegible]
Preservation of freedom of choice for future resource use	+1 - Resources reserved for future use.	-1 - Curtailment of future options for resource.	[illegible]
Totals	- = 0 0 = 16 +1 = 1	- = 1[illegible] 0 = 4 + = 3	- = [illegible] [illegible] + [illegible]

[illegible] Key: -2 = Significant loss or long-term effects.
-1 = Slight loss or short-term effects.
0 = Status quo.
+1 = Slight gain or short-term effects.
+2 = Significant gain or long-term effects.

Summary of Alternatives

Alternative 1 (no action) would have the least overall environmental effect. Alternatives 2 and 4 indicate economic feasibility for a new water [illegible] structure at the Days High Landing site. Alternative 2 would include a canoe and small-boat portage; alternative 4 would include a large-boat mobile lock. Alternative 2 has the highest net benefits and is designated the economic development plan. Alternative 4 is marginally feasible.

Cultural Resources

The headwaters lakes region contains numerous significant prehistoric and historic sites. The Corps has conducted surveys to identify these sites in some areas of the headwaters region. But not all sites in the area have been located. Any action taken to implement any proposed solution to this problem may have an impact on cultural resources, particularly those alternatives that would increase lake levels, e.g., alternatives 2, 3, 4, and 5.

Prior to implementation, additional surveys will need to be conducted within the project area. All sites located within the area that may be affected by the proposed project will need to be tested to determine their significance. All significant sites listed on or eligible for inclusion on the National Register of Historic Places will need to be mitigated in accordance with Advisory Council on Historic Preservation regulations, 36 CFR 800, prior to construction.

Recommendations

The recommendation for no further studies is based on the above items and the direction of the State of Minnesota concerning the proposed Days High Landing Dam. The Minnesota Department of Natural Resources advised the St. Paul District by letters (dated 25 March 1977, 28 August 1978, and 31 January 1979) that the State favors designating the White Oak Lake stretch of the Mississippi River above Days High Landing as "scenic" and opposes a dam proposal in that area. The no action alternative (alternative 1) is recommended, and no further studies are recommended.

Alternative 1: Base Condition (No Action)

The base condition in the Black Bear and Miller Lakes area consists of floodplain regulation and flood insurance required by Federal policies and encouraged by the State of Minnesota. The 1973 National Flood Disaster Protection Act established a program of Federal assistance intended to relate flood insurance to a unified national program for floodplain management. The 1973 act expanded and improved on an earlier 1968 flood insurance program.

Black Bear and Miller Lakes residents (Crow Wing County, Minnesota) are eligible for flood insurance with subsidized premium rates under the 1973 insurance program. Flood insurance with subsidized premium rates is available in amounts up to $35,000 for a single family dwelling and up to $100,000 for multifamily and nonresidential units. Insurance on contents is available to a maximum of $10,000 per unit for residences and $100,000 for nonresidential units.

Crow Wing County residents will be able to participate in a regular flood insurance program which uses actuarial flood insurance rates determined from detailed floodplain surveys, as soon as floodplain surveys are completed and regulations are developed. Under the regular program with a flood insurance rate map, coverage up to double the above amounts will be available at subsidized or actuarial rates, or both, depending on whether construction or improvement was started on or after 31 December 1974 or the effective date of the flood insurance rate map.

Flood insurance does not prevent flood damages but assists in reimbursing affected property owners for losses sustained from flood damages. It is most effective when used in conjunction with floodplain regulations and other measures. If insurance is properly administered, all premiums except that portion used for administration would be returned to property owners through payments for damage. Flood insurance is not considered a complete or effective means of reducing or controlling flood prone area damages in the Black Bear-Miller Lakes areas. However, flood insurance used as a supplement to floodplain regulations could provide limited economic protection for existing Black Bear-Miller Lakes flood prone area development and appears to be the only economically feasible solution at the present time.

Alternative 2: Flood Warning and Forecasting Services and Emergency Protection

Flood warning and forecasting services for Aitkin (just upstream from the Black Bear-Miller Lakes area) are provided by the National Weather Service forecast office in Minneapolis. Warnings of flood stages and crest forecasts can be provided from 3 days in advance for rainfall runoff up to 1 month in advance for snowmelt runoff.

Emergency flood protection in the form of individual home diking could possibly be built in advance of a snowmelt flood if the longer period of warning time were available. However, it is against Corps policy to provide emergency flood protection for private property where no public facilities are involved. Also, emergency diking of individual homes would not be possible in the event of a rainstorm-caused flood. The emergency ring diking would have to be removed after each flood or it would disrupt the biological systems and scenic quality of lakeshore properties.

Advance flood warnings would help prevent some of the overall economic loss to private property by allowing time for moving contents of homes and other valuables to more secure areas. However, all of the above emergency measures would cause much personal inconvenience and continued disruption to floodplain residents.

Flood warning and forecasting services and emergency protection measures are not considered socially, economically, or environmentally acceptable as a total solution to the Black Bear-Miller Lakes flood problem. However, flood warning and forecasting services will continue to provide a valuable service to Black Bear-Miller Lakes residents.

Alternative 3: Flooded Area Evacuation

Permanent evacuation of the developed floodplain area around Black Bear and Miller Lakes would involve purchasing lands, removing and relocating improvements, evacuating and resettling residents, and converting evacuated land to uses less susceptible to flood damage. Lands acquired in this manner could be used for park or "natural" areas or other purposes which would not be damaged so severely by floods.

Evacuation would affect 28 of the 37 cabins and homes located around Black Bear and Miller Lakes. Most of the affected buildings would be purchased rather than moved because of their age and condition. Purchased buildings would be sold at public auction. The total first cost of this alternative is $1,200,000, giving it an unfavorable benefit-cost ratio of 0.14.

Alternatives 4, 5, 6: Flood Proofing

Alternatives 4, 5, and 6 involve flood proofing buildings subject to flooding. Flood proofing includes a combination of various structural changes and adjustments to buildings to reduce or eliminate flood damages. In most instances, flood proofing involves elevating buildings above the 100-year flood level or sealing off building openings to prevent water from entering window wells or floor drains.

Alternatives 4, 5, and 6 evaluate the merits of raising the 28 flood prone properties by means of earth fill, wood piling, and concrete block, respectively. Each alternative also includes elevating the access roads to the properties. Both the properties and access roads would be elevated as required under Minnesota floodplain regulations. The flood proofing alternatives would lack economic feasibility even if the raised access roads were not required. (In this instance, access during floods would be by boat, which is the current method used by residents to reach their properties during floods.) With the three alternatives, vault toilets would be used for sanitary facilities because they would be considerably cheaper than individual holding tanks or group collection with package plant systems. None of the three flood proofing systems were feasible, having respective first costs of $1,219,000, $906,000, and $898,000 and respective benefit-cost ratios of 0.13, 0.17, and 0.17.

Alternative 7: Raise Existing Dam

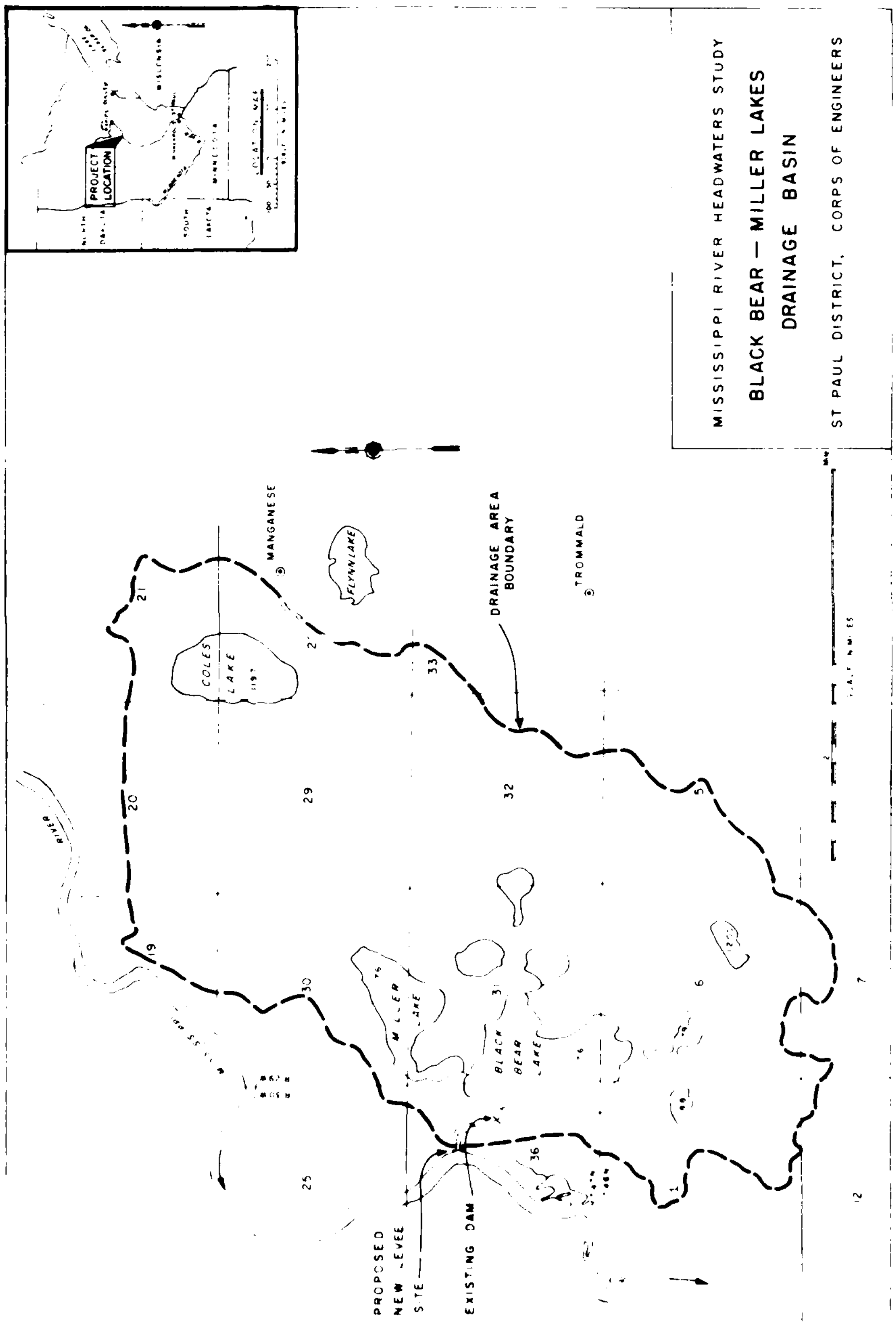
The existing WPA dam was constructed on the natural outlet of Black Bear Lake during the 1930's. It is a low head, two-bay, concrete stop log control structure that would be overtopped by 7 feet of water during a 100-year flood event. Raising the dam is not feasible, and the surrounding ground near the dam is not high enough to provide 100-year flood protection even if the dam could feasibly be raised.

Alternative 8: Construct New Levee

This alternative would consist of constructing a rolled earthfill levee downstream from the existing WPA dam on the unnamed stream that leads from Black Bear Lake to the Mississippi River. This site constitutes a natural control location, with high embankments on either side of the stream before it enters the Mississippi River.

The levee would be 20 feet high at the deepest point in the stream and 160 feet long at the top, with a 12-foot top width and 3:1 side slopes both upstream and downstream. An inspection trench would be constructed for the full length of the levee and would be filled with impervious material. The outlet structure would consist of a concrete gate well, a concrete culvert pipe, and a slide gate. The structure would function as a barrier to prevent Mississippi River water from backing into the Black Bear-Miller Lakes area. The slide gate would remain open except during flood periods on the Mississippi River. No pumping is required to handle interior drainage during a Mississippi River flood because Black Bear and Miller Lakes (approximately 320 acres) can fluctuate 1 foot without causing damage to the shoreline or homes.

This alternative is the most practical of the structural alternatives and is economically feasible. The levee has a first cost of $128,000 and a benefit-cost ratio of 1.22. The location of the proposed levee is shown on the following figure.



MISSISSIPPI RIVER HEADWATERS STUDY
BLACK BEAR — MILLER LAKES
DRAINAGE BASIN
ST PAUL DISTRICT, CORPS OF ENGINEERS
PROJECT LOCATION
MANGANESE
FLYNN LAKE
COLES LAKE
DRAINAGE AREA BOUNDARY
TROMMALD
RIVER
MILLER LAKE
BLACK BEAR LAKE
PROPOSED NEW LEVEE SITE
EXISTING DAM

[illegible]

[illegible] structur[illegible] and nonstr[illegible] alternatives are summari[illegible] in the following table.

Summary of [illegible] Bear-Miller Lakes [illegible] Alternatives

Alternative	First cost	Annual cost (1)	Annual benefit	Benefit-cost ratio
1. Base condition (flood insurance) (2)	-	[illegible]	[illegible]	[illegible]
2. Flood warning and fore-casting (3)	-	-	-	[illegible]
3. Evacuation	$1,200,000	91,600	13,40[illegible]	[illegible]
4. Flood proof on fill (vault toilets)	1,219,000	102,000	13,40[illegible]	0.1[illegible]
5. Flood proof on piling (vault toilets)	906,000	77,300	13,400	0.17
6. Flood proof on block walls (vault toilets)	898,000	75,900	13,400	0.17
7. Raise existing dam (4)				
8. Construct closure structure (levee)	128,000	11,000	13,400	1.22

(1) Based on a 100-year project life and a 7 5/8-percent interest rate. Includes operation and maintenance costs.
(2) Flood insurance benefits are assumed to equal costs.
(3) Costs and benefits would vary for emergency evacuation or protection measures depending on the magnitude of the flood predicted.
(4) Not feasible from an engineering standpoint.

Alternatives Considered Further

Alternatives 1 through 6 are considered nonstructural options and alternatives 7 and 8 are considered structural approaches. All of the alternatives except alternative 7 are compared with each other in the following paragraphs, in accordance with the Principles and Standards. Alternative 7 is not feasible from an engineering standpoint.

Contribution of Alternatives to Specific Planning Objectives

The following table ranks the alternatives according to their contributions to specific planning objectives; alternative 8 ranks the highest.

Black Bear and Miller Lakes flood control - rating of alternatives

Specific planning objectives	Plan satisfaction rating: High			
Economic feasibility	Alternative 8	Alternatives 1 and 2	Alternatives 6, 5 and 4	Alterna[illegible]
Preserve and enhance the quality of the present area environment	Alternative 3	Alternative 8	Alternatives 1 and [illegible]	Alternativ[illegible] 5, and [illegible]
Enhance the economic welfare of the basin population	Alternative 8	Alternatives 6, 5, and 4	Alternatives 1 and [illegible]	Alterna[illegible]
Minimum disruption to man-made or natural resources	Alternative 8	Alternatives 1 and 2	Alternative[illegible]	Alternatives [illegible], [illegible], and 6
Social acceptability	Alternative 8	Alternatives 1 and 2	Alternatives [illegible], 5, and [illegible]	Alternative[illegible]
Local cooperation	Alternative 8	Alternatives 1 and 2	Alternatives 6, [illegible], [illegible] 4	Alternative[illegible]

Alternative 1: Base condition (flood insurance).
Alternative 2: Flood warning and forecasting.
Alternative 3: Evacuation.
Alternative 4: Flood proof on fill.
Alternative 5: Flood proof on piling.
Alternative 6: Flood proof on block walls.
Alternative 8: Construct closure structure (levee).

Contribution of Alternatives to National Objectives

The contribution made by each alternative to the two national objectives of economic development and environmental quality must be evaluated. The Principles and Standards require that a national economic development plan and an environmental quality plan be identified. Normally a nonstructural plan is also identified; in this case, the nonstructural plans are alternatives 1, 2, 3, 4, 5, and 6.

The national economic development plan is that plan which maximizes net economic benefits while addressing the range of planning objectives. National economic benefits are determined by measuring and analyzing the net value of increases in goods and services derived from the plan. The national economic development plan is alternative 8.

An environmental quality plan must make a net contribution to environmental values while addressing the planning objectives. The environmental quality plan is alternative 3 contingent on minimal impacts at the relocation site. The following table summarizes the environmental impacts of each alternative.

Environmental quality item	Alternative [illegible] and Flood insurance and warning	Alternative [illegible] Evacuation	[illegible]	[illegible]
Wild and scenic rivers	[illegible] - No change.	[illegible] - No change.	[illegible] - No change.	[illegible] - No change.
Natural streams	[illegible] - No change.	[illegible] - No effect.	[illegible] - No effect.	[illegible] - Levee will [illegible] present Mississippi River [illegible] natural stream.
Beaches	[illegible] - No change.	0 - No change.	0 - No change.	+2 - Improve[illegible] beaches [illegible] and [illegible]
Archeological/historical	0 - No change.	0 - No known sites affected.	[illegible] - No known sites affected.	[illegible] - No known sites [illegible]
[illegible]	0 - No change.	-2 - 28 of 37 units removed from the floodplain.	0 - No effect.	[illegible] - No effect.
Aesthetic values	0 - No change.	+1 - Increase in natural setting.	-1 - Loss of [illegible] space.	[illegible] - [illegible] improvement [illegible] provide[illegible].
Open space	0 - No change.	+1 - Less developed shoreline.	0 - No change.	[illegible] - [illegible] shoreline [illegible]
Land quality	0 - No change.	+1 - Shoreline would be open to public.	0 - No change.	[illegible] - Improved land [illegible] with [illegible]
Recreation	0 - No change.	+1 - More public access to two lakes.	0 - No change.	-1 - Loss of [illegible] access [illegible] Mississippi River.
Air quality and noise	0 - No change.	-1 - Major disruption during removal of buildings.	-1 - Some disruption during construction.	-1 - Some disruption during construction.
Streambank erosion	0 - No change.	0 - No change.	0 - No change.	0 - No change.
Water quality	0 - No change.	+1 - Improved water quality.	+1 - Improved water quality due to improved sanitary facilities.	[illegible] - Less siltation from Mississippi River.
Biological resources	0 - No change.	+2 - Moderate improvement in lake ecosystems.	+1 - Some improvement in lake ecosystems due to improved sanitary facilities.	+1 - Less [illegible] ecosystems [illegible]
Rare and endangered species	0 - No change.	0 - No known effect.	0 - No known effect.	0 - No known effect.
Ecological systems				
Terrestrial	0 - No change.	-1 - Minor habitat gains in evacuated area; some losses in resettlement areas.	-2 - Detrimental effect due to added filling and construction.	[illegible] - Minimal detrimental effect.
Aquatic	0 - No change.	+1 - Reduced pollutants entering lakes.	-1 - Increased sediment from construction activities.	[illegible]
Preservation of freedom of [illegible] for future resource use	[illegible] - No change.	-1 - Future options curtailed.	[illegible] - Future options curtailed.	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

The Black Bear-Miller Lakes area lies in the segment 5 reach of the Upper Mississippi River Wild and Scenic Rivers proposal. However, the proposal has had difficulty in gaining approval by Congress and, at present, the area is not part of the Federal or State Wild and Scenic Rivers system. Consequently, the preceding table was prepared for current conditions (no Wild and Scenic River designation). The table would change if this reach of the river were included in the Wild and Scenic Rivers system.

Summary of Alternatives

The primary objective of the alternatives investigated is to provide flood protection for the Black Bear and Miller Lakes residents. The area experiences flood damage on a 3- to 5-year interval, and up to 28 of 37 units located around the two lakes are subject to property damage.

Alternative 8 (new levee) best meets the specific planning objectives, whereas alternative 3 (evacuation) appears to be the best plan from an environmental standpoint. Alternatives 1 and 2 combined (flood insurance and warning) appear to be less satisfactory.

Discussion

The State of Minnesota or Crow Wing County would be a logical sponsor for a new water control structure at the outlet of Black Bear Lake. Initially, neither expressed interest in sponsoring the proposed project. The two townships involved are not legally acceptable sponsors for Corps projects because they lack independent taxing and condemnation authority.

The State owns the land (Minnesota School Trust lands) where the structure would have to be built. It also owns the present dam that controls Black Bear Lake and overtops during Mississippi River floods.

The Minnesota Department of Natural Resources recommends local sponsorship (county-township) of the project because it addresses local problems and has limited or no State or regional importance. The State will not sponsor the project without special legislative funding, support, and approval for future State operation and maintenance when completed.

Crow Wing County recently (4 May 1982) agreed to support the proposed project and act as local sponsor. The State of Minnesota has agreed to give a permanent easement for the structure since the State is prohibited by law from selling the school lands.

Cultural Resources

The headwaters lakes region contains numerous significant prehistoric and historic sites. The Corps has conducted surveys to identify these sites in some areas of the headwaters region. But not all sites in the area have been located. Any action taken to implement any proposed solution to this problem may have an impact on cultural resources except alternatives 1 and 2 which do not include any ground disturbing impacts.

Prior to implementation, additional surveys will need to be conducted within the project area. All sites located within the area that may be affected by the proposed project will need to be tested to determine their significance. All significant sites listed on or eligible for inclusion on the National Register of Historic Places will need to be mitigated in accordance with Advisory Council on Historic Preservation regulations, 36 CFR 800, prior to construction.

Recommendations

Six nonstructural and two structural plans were considered for the Black Bear-Miller Lakes flood problem. None of the nonstructural alternatives is economically feasible except for the flood insurance floodplain regulation alternative (alternative [illegible]).

Structural alternative [illegible] is also economically feasible and should be evaluated in greater detail. The Black Bear-Miller Lakes flood problem will not be evaluated further under the Mississippi River Headwaters study. However, an interim study will be conducted under the small project authority, in the interest of accelerating the study process, with Crow Wing being the local sponsor for this proposed project. An environmental assessment would be prepared as part of that study and a 404(b)(1) evaluation would probably be required if a levee alternative were selected.

HEADWATERS LAKES PERIMETER DIKES - PROBLEM 6

Beginning in the late 1800's, perimeter dikes were constructed at several of the headwaters lakes to prevent impounded water from seeking alternate overflow outlets and causing damage. The need for this diking was based on maximum flowage limits and on original topographic data that may have been inaccurate in some areas. The approximate dike locations are shown on the figure on page 75.

Alternative 1: Base Condition (No Action)

The base condition consists of allowing the existing 28 dikes to function as they have since the late 1800's with only periodic inspection by the St. Paul District and limited maintenance. In some cases, heavy tree growth has almost obscured the presence of these dikes. In other cases, they are a part of existing county road systems. Present maintenance involves primarily mowing and normal road maintenance for only the perimeter dikes that are part of the existing headwaters site or county road systems. Present maintenance costs for this work are negligible. The locations of some dikes show that they are on property outside Government-owned right-of-way.

The cost of this alternative is limited to the value of periodic inspections by the St. Paul District and the time and effort spent in writing inspection reports. The cost of this alternative is $130,900 based on another 100-year structure life for each dike, annual maintenance inspections, and engineering inspections conducted once every 5 years. Comparable benefits have not been developed in this study. Benefits under this alternative should at least be equal to the costs of inspection.

Alternative 2: Upgrade Existing Dikes

This alternative considers upgrading the existing 28 dikes to withstand standard project flood design elevations. All 28 perimeter dikes would be cleared of brush and trees and the roots would be grubbed from the dikes. Most of the dikes would be protected with riprap, and dikes that do not meet design top width and height would be rebuilt to the desired level and cross section. All 28 dikes would be maintained and mowed regularly. Only the four Sandy Lake, two Pokegama, and three Winnibigoshish dikes actually require raising to meet standard project flood criteria with this alternative.

The first cost of this alternative is $9,716,400; the benefit-cost ratio is 0.61.

Although this alternative is not cost effective in total, it appears cost effective for the Pine River and Pokegama Lakes area as shown in the following table.

Upgrade perimeter dikes(1) -
Summary of structural plan cost data

Lake area	First cost	Annual maintenance cost	Total annual cost(2)	Annual benefit	Benefit-cost ratio
Pine River	$684,500	$5,900	$58,100	$297,900	5.13
Pokegama	14,600	800	1,900	1,700	0.89
Sandy	8,757,600(3)	2,900	668,200	155,600	0.23
Winnibigoshish	259,700	1,600	21,400	0	0
Total	9,716,400	11,200	752,500	455,200	0.61

(1) Includes raising nine dikes identified previously.
(2) Based on a 100-year project life and a 7 5/8-percent interest rate. Includes annual operation and maintenance costs.
(3) Approximately $8 million would be allocated to construct a new Sandy Lake control structure.

Alternative 3: Dispose of Existing Dikes

At least 12 of the 28 perimeter dikes are located entirely or partially on lands not owned in fee title by the United States Government. Consequently, another alternative might be simply to turn over any Federal interest in the dikes to present landowners.

The estimated first cost of this alternative is $13,400. This relatively small amount would be used for administrative expenses for disposing of the 28 parcels. This alternative does not appear desirable as the dikes were constructed originally to prevent lake overflow to adjacent lands and loss of storage during high water, and it would not be in the best interest of the Government to take this action.

Alternative 4: Clear and Maintain Dikes

This alternative consists of grubbing and clearing trees and brush from all 28 dikes and providing annual maintenance, as in alternative 2. The first cost of this alternative is $25,800. The benefit-cost ratio is 34.3.

Review of Alternatives

Cost data for the structural and nonstructural alternatives are summarized in the following table.

Headwaters Lakes perimeter dikes -
summary of cost data for alternatives

Alternative	First cost	Annual cost (1)	Annual benefit	Benefit-cost ratio
1. No action	$130,900	$9,900	$8,700 (2)	0.88
2. Upgrade existing dikes	9,716,400	749,600	455,200	0.61
3. Dispose of existing dikes	13,400	1,000	11,300 (3)	11.3
4. Clear and maintain dikes	25,800	13,280	455,700	34.3

(1) Based on 100-year project life and 7 5/8-percent interest rate. Includes annual operation and maintenance costs.

(2) Amount equal to the cost of inspections.

(3) Estimated proper annual maintenance costs.

(4) $11,300 in annual operation and maintenance costs.

Alternatives Considered Further

Alternatives 3 and 4 and alternative 2 applied to the Pine River and Pokegama Lakes areas would normally be considered further, as they show economic feasibility. However, alternative 3 does not appear to be implementable in that the Government has a responsibility to adjacent landowners and to vested water interests in the Mississippi River Headwaters Lakes areas and downstream areas.

Alternative 4 appears economically justified and meets the national objectives of economic development and environmental quality. This alternative should be pursued together with the economically feasible portion of alternative 2 applied to the Pine River and Pokegama Lakes areas.

Cultural Resources

The headwaters lakes region contains numerous significant prehistoric and historic sites. The Corps has conducted surveys to identify these sites in some areas of the headwaters region. But not all sites in the area have been located. Any action taken to implement any proposed solution to this problem may have an impact on cultural resources, particularly any solution that would include ground disturbing activities such as clearing, upgrading, or removing existing dikes.

Prior to implementation, additional surveys will need to be conducted within the project area. All sites located within the area that may be affected by the proposed project will need to be tested to determine their significance. All significant sites listed on or eligible for inclusion on the National Register of Historic Places will need to be mitigated in accordance with Advisory Council on Historic Preservation regulations, 36 CFR 800, prior to construction.

Recommendations

Recommendations for further studies of the headwaters lakes perimeter dikes follow:

a. No further investigation of the 28 perimeter dikes is recommended under the Mississippi River Headwaters Lakes study authority. The 28 perimeter dikes should be included for detailed inspection and testing in the District's regular scheduled maintenance program. The dikes that require additional height to meet standard project flood criteria could not be economically justified, except possibly those for Pokegama Lake. The Pine River dikes, which do not require raising but would require riprap protection, appear to be economically justified.

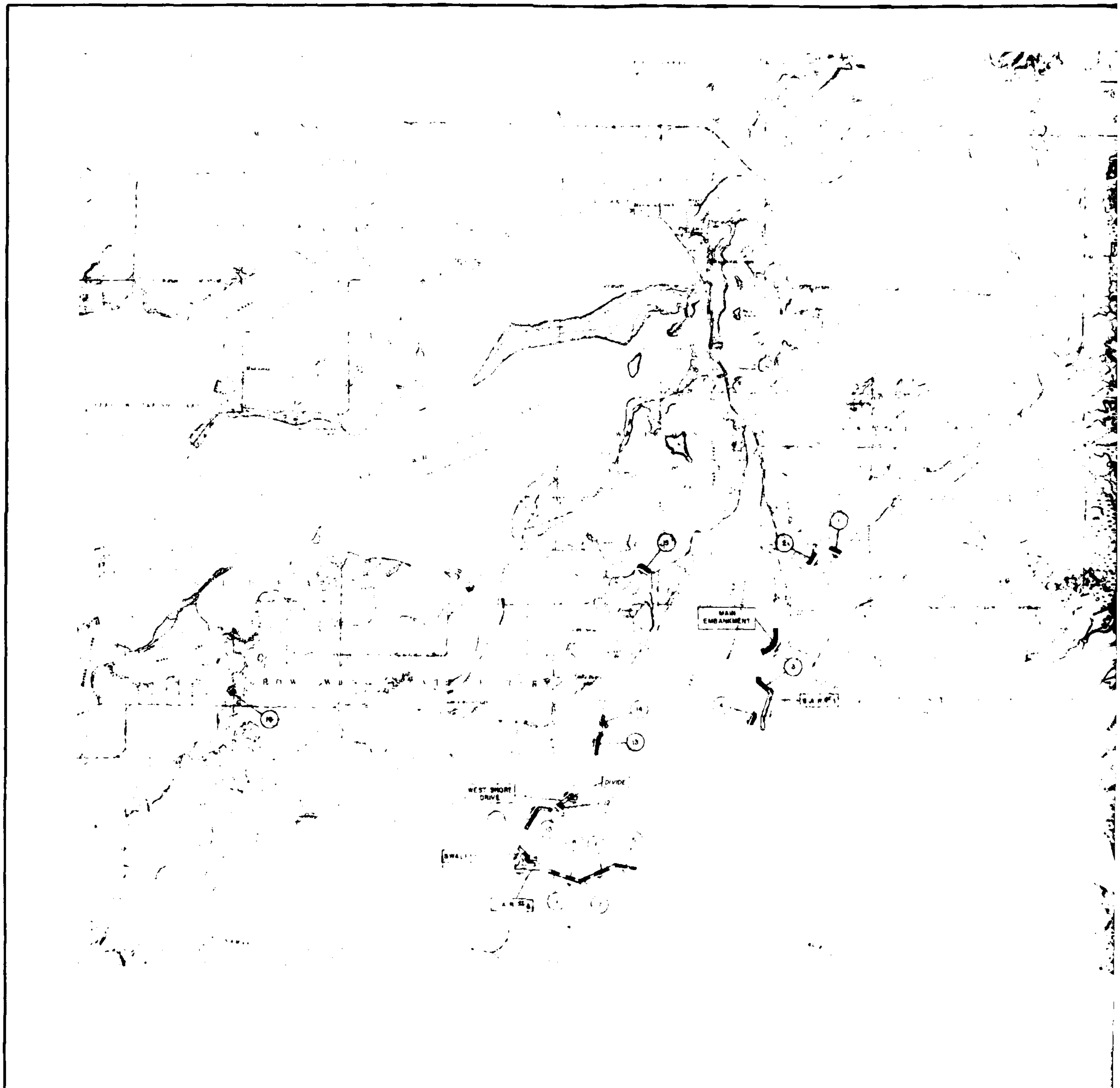
b. Sixteen Pine River and two Pokegama Lake dikes should be scheduled for upgrading with riprap protection and/or raising as concluded in this study. The riprap protection work would be accomplished under the present operations and maintenance authority. However, the Corps of Engineers would have to obtain additional authority to pursue raising any perimeter dikes. The remaining 10 perimeter dikes on Pokegama, Winnibigoshish, and Sandy Lakes should be cleared of brush and trees and properly monumented, except for dike 1 at Lake Winnibigoshish. This dike could not be located under an existing roadway.

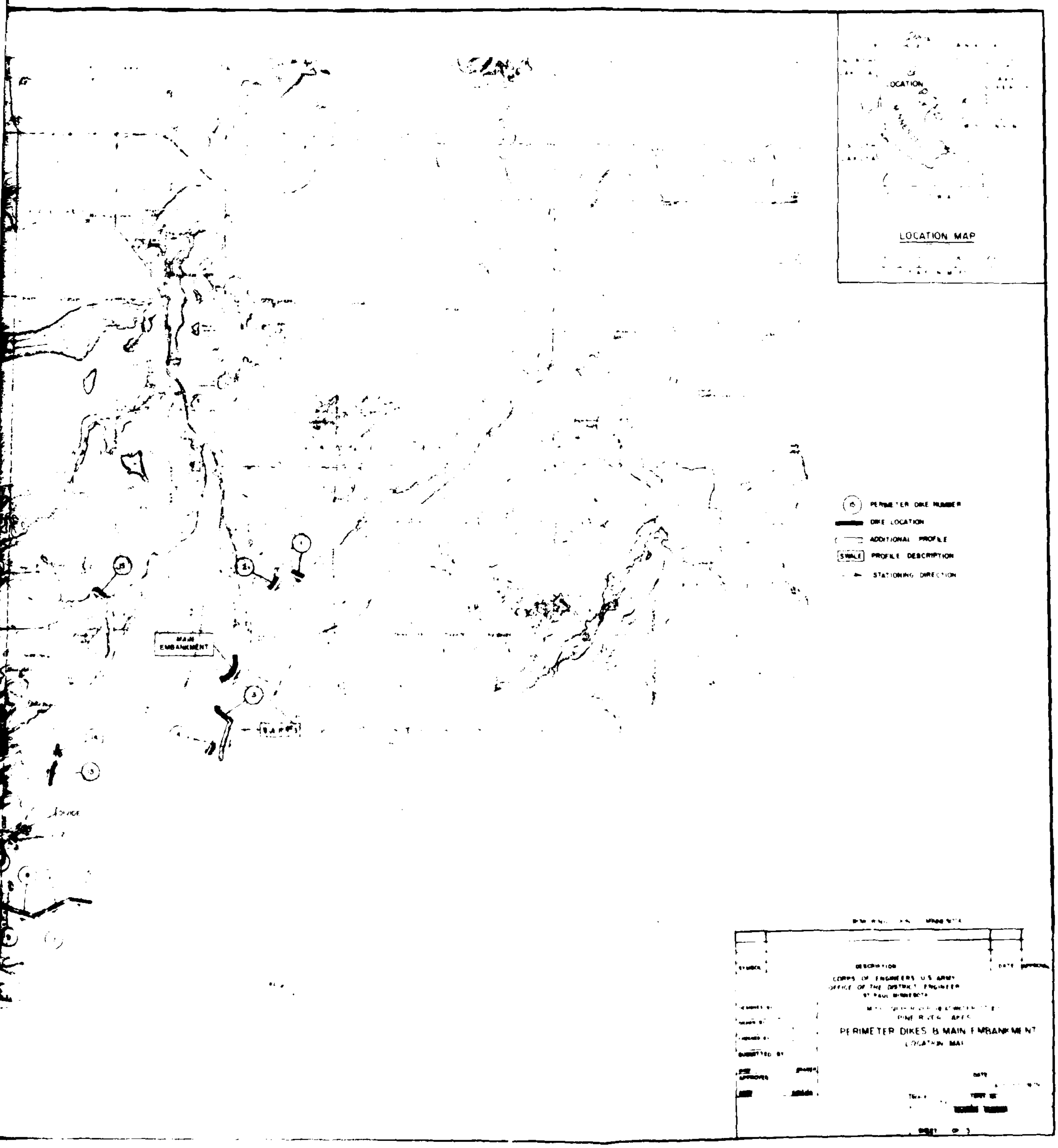
c. Dikes 13, 14, 15, and 16 at the Pine River Lake area should be closely monitored for the known seepage problem and a final solution should be developed and implemented under the Corps operation and maintenance authority. A location map, profile, and cross sections for these two dikes are shown on the following three figures.

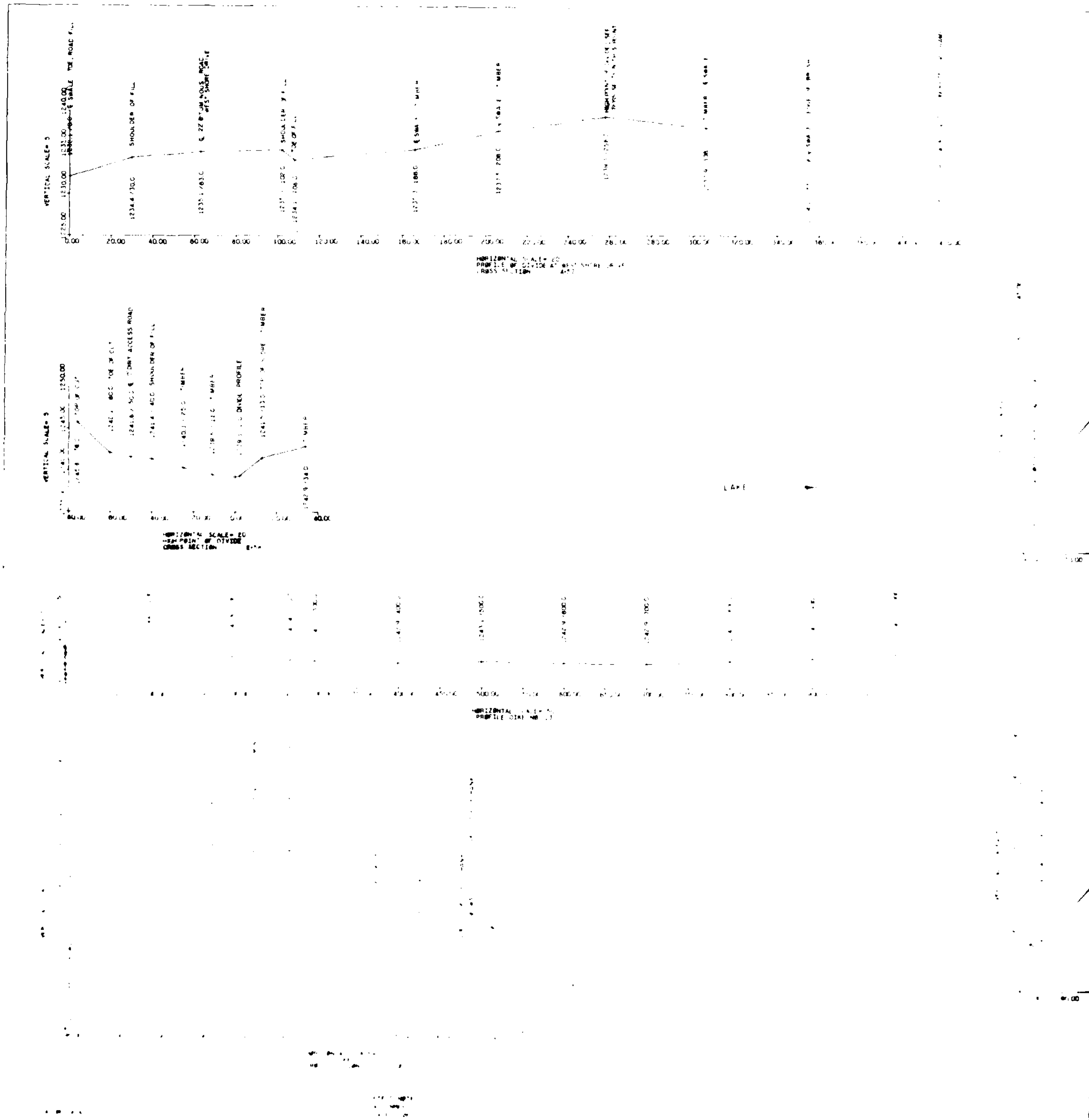
d. The perimeter dikes should be included in further evaluations under the relatively new Corps of Engineers Dam Safety Assurance Program. This program is in response to a 23 April 1977 Executive Memorandum on Dam Safety and essentially provides that federally owned dams be classified according to the various hazard categories currently applied to non-Federal dams. If under this program perimeter dikes are found to be hazardous to human life, they snould be upgraded to specific design standards.

e. An additional survey is needed to locate all of the dikes in plan view. The purpose of this survey would be to locate the ends of each dike and monument them for future reference and for possible acquisition of property. The dikes should then be recorded on site plan maps of sufficiently detailed scale. Additional dike cross section work is also required to better define accurate work quantities. The 28 dikes should all be cleared of brush and trees prior to monumentation except for dike 1 at Lake Winnibigoshish which could not be located under an existing roadway.

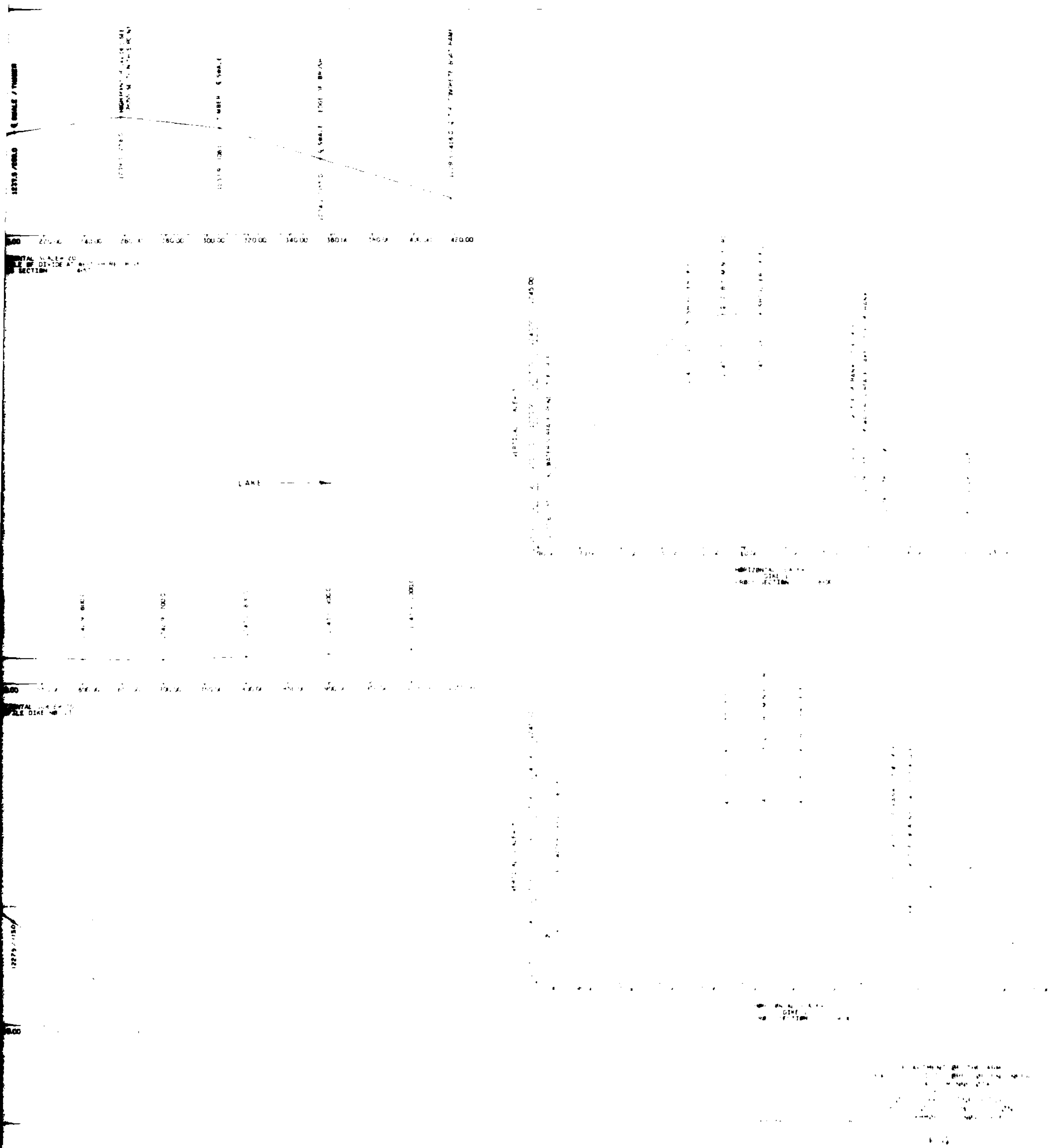
f. Environmental assessments would be conducted under the operation and maintenance program whenever changes to the perimeter dike system were required. Loss of wildlife habitat may be expected if vegetation is cleared or dikes raised.

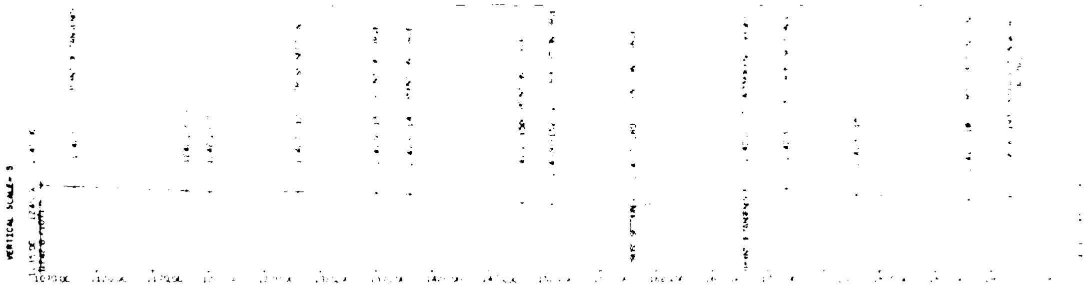

MAIN EMBANKMENT
WEST SHORE DRIVE
DIVIDE


LOCATION MAP
MAIN EMBANKMENT
PERIMETER DIKE NUMBER
DIKE LOCATION
ADDITIONAL PROFILE
SWALE
PROFILE DESCRIPTION
STATIONING DIRECTION
DESCRIPTION
SYMBOL
DATE
APPROVAL
CORPS OF ENGINEERS U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER
ST. PAUL MINNESOTA
PINE RIVER LAKES
PERIMETER DIKES & MAIN EMBANKMENT
LOCATION MAP
SUBMITTED BY
APPROVED
DATE
SHEET OF 3



VERTICAL SCALE= 5
SHOULDER OF FILL
HORIZONTAL SCALE= 20
CROSS SECTION
VERTICAL SCALE= 5
DIVIDE PROFILE
LAKE
HORIZONTAL SCALE= 20
HIGH POINT OF DIVIDE
CROSS SECTION


LAKE



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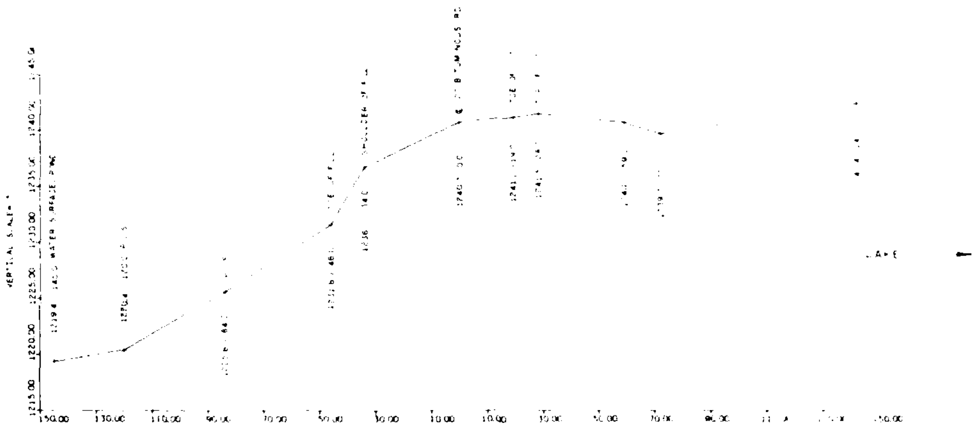
PROFILE LINE NO 14



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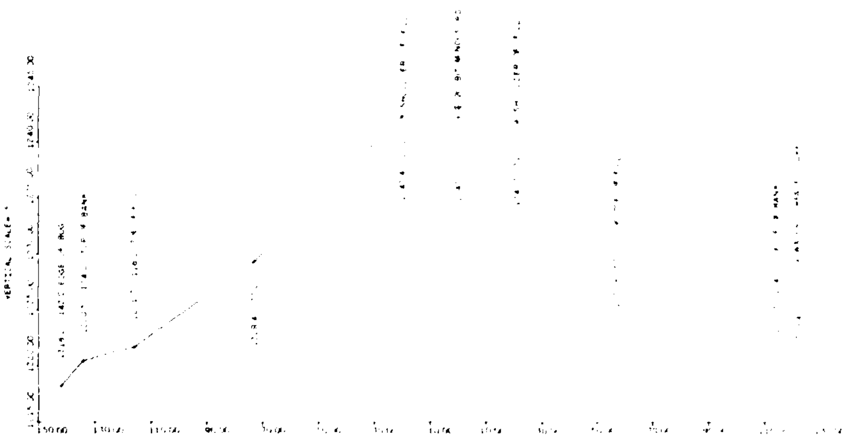
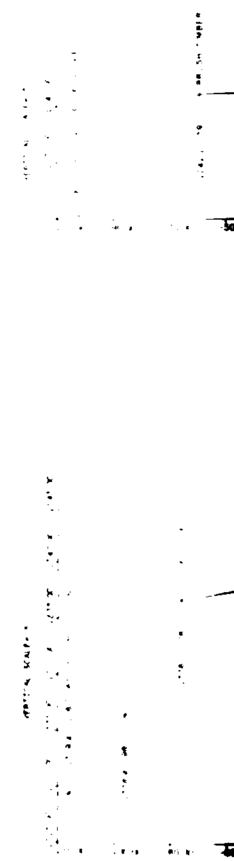
DIKE 14
CROSS SECTION 18+00



HORIZONTAL SCALE= 20
DIKE 14
CROSS SECTION



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FIELD NOTES
ALIGNMENT
PAGE

Scale of Development

The perimeter dikes were evaluated for upgrading to the standard project flood level. A comparison of the standard project flood level with the 100-year (1-percent chance occurrence) levels and with top of dike levels is shown in the following four tables.

Headwaters Lakes perimeter dikes - comparison of standard project flood and 100-year flood levels

Lake area	100-year level (1929 adjustment)	Standard project flood level	Recommended design level (standard project flood) (1929 adjustment)
Winnibigoshish	1302.90	1304.44	1308.6
Leech	1297.00	1297.10	1300.3
Pokegama	1277.90	1277.97	1280.9
Sandy	1223.90	1226.81	1229.8
Pine River	1232.80	1234.32	1237.3
Gull	1195.40	1197.65	1200.7

LAKE DATA - Mississippi River Headwaters Perimeter Dikes and Main Embankments

Item	Winnibigoshish		Leech	Pokegama		[illegible]		[illegible]		[illegible]
1. [illegible]										
a. Normal pool elevation, feet msl	1299		1296	1273		[illegible]		[illegible]		[illegible]
b. [illegible] imum observed lake elevation, feet msl	1303.17		1297.07	1277.89		[illegible].82		[illegible]		[illegible]
c. 100-year flood elevation, feet msl	1302.90		1297.0	1277.9		[illegible]		[illegible]		[illegible]
2. [illegible] REFERENCE LEVEL (Standard Project Flood)										
a. [illegible] ervoir elevation, feet	1304.44		1297.10	1277.97		[illegible].8[illegible]		[illegible]		[illegible]
3. [illegible]	Minimum	Maximum		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	
a. [illegible] for wave computations, miles	9.5	11.2	4.0	0.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
b. [illegible] used in wind tide computations (assumed as 2Fe), miles	19.0	22.4	8.0	0.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4. [illegible] DESIGN WIND										
a. [illegible] hours	1.43	1.62	0.75	0.20	0.53	[illegible]	0.48	[illegible]	[illegible]	[illegible]
b. Average overland velocity, mph	40		40	40		[illegible]		[illegible]		[illegible]
5. [illegible]										
a. [illegible] used in computations, feet	20	38	8.7	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
b. [illegible] above FRL, feet	1.0	1.7	[illegible].7	0.1	0.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6. [illegible]										
a. [illegible] reduction for breaking waves or [illegible], feet msl	[illegible].3	[illegible]	3.[illegible]	1.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
b. [illegible] for perimeter dikes and [illegible]	2.0	4.3	2.1	1.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
c. [illegible] (1.67 H[illegible]) for perimeter dikes and [illegible] msl	3.3	7.2	3.[illegible]	2.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7. [illegible] EMBANKMENT SECTION WITH RIPRAP										
a. [illegible] above FRL, feet	[illegible]	[illegible]	[illegible]	1.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
b. [illegible] (items 2a + 5b + 7a)	1308.[illegible]	1311.[illegible]	[illegible]	1279.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8. [illegible] EMBANKMENT SECTION WITHOUT RIPRAP										
a. [illegible]	3.[illegible]	3.[illegible]	[illegible]							
b. [illegible] above FRL [illegible]	4.2	6.8	3.2	[illegible]						[illegible]
c. [illegible] embankment (items 2a + [illegible]), feet msl	[illegible]	1311.2	[illegible]	1281.[illegible]	128[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

[illegible] waves breaking in shallow water
[illegible] vegetated [illegible], where applicable.
[illegible] of free[illegible] is required.

AD-A130 354 MISSISSIPPI RIVER HEADWATERS LAKES IN MINNESOTA FEASIBILITY STUDY MAIN REPORT(U) CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT SEP 82

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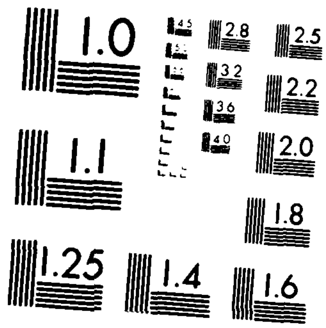

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Mississippi River Headwaters Lakes - Perimeter Dikes Existing Embankment Characteristics

Lake	Dike No.	Freeboard Reference Level (feet)	Max. Elev. Attained with Design Wave (feet)	Existing Controlling Dike Elevation (feet)	Existing Dike Overtopped	Existing Slope Protection on Lake Side of Embankment	Existing Dike Side Slope: Lake	Existing Dike Side Slope: Land	Existing Dike Top Width (feet)
SANDY									
(Main Embankment)	1	1226.81	1230.1	1227.9	yes (2.3 ft.)	[illegible]	1 on 2.5	[illegible]	[illegible]
	2	"	1229.5	1225.1	yes (4.4 ft.)	[illegible]	1 on 3	1 on 3	8
	3	"	1229.6	1225.7	yes (3.9 ft.)	Riprap	1 on 3	1 on 3	[illegible]
	4	"	1228.5	1227.2	yes (1.3 ft.)	Brush	[illegible]	[illegible]	[illegible]
POKEGAMA									
(Main Embankment)	-	[illegible]	1279.8	1279.4	yes ([illegible] ft.)	Riprap	[illegible]	[illegible]	
	1	"	1282.1	1283.1	no	Brush	[illegible]	[illegible]	[illegible]
	2	"	1282.1	1279.9	[illegible]	Trees	[illegible]	1 on 3	[illegible]
	3	"	1282.1	1284.0	no	[illegible]	[illegible]	[illegible]	[illegible]
	4	"	----	[illegible]	yes[1]	Trees	[illegible]	1 on 2	[illegible]
(Roadway near Dike No. 2)	-	"	1280.7	1279.2	yes (1.5 ft.)	Trees	1 on [illegible]	1 on 2	[illegible]
WINNIBIGOSHISH									
(Main Embankment)	-	[illegible]	1315.9	1303.9	yes (6.[illegible] ft.)	Riprap	1 on 2	1 on 2	26
	1	"	----[2]	----	----	----	----	----	--
	2	"	1310.4	1303.2	yes (7.2 ft.)	Trees	1 on 2	1 on 36	[illegible]
	3	"	1310.4	[illegible]	yes ([illegible] ft.)	Trees	1 on 2	1 on 1.5	[illegible]
	4	"	1310.4	1306.0	yes (4.4 ft.)	Trees	1 on 2	1 on 3	[illegible]
PINE RIVER (CROSS LAKE)									
(Main Embankment)	-	1234.3	1238.1	1237.5	yes (0.6 ft.)	Riprap	1 on 3	1 on 2	8
	1	"	1236.5	1243.7	no	Brush	1 on 5	1 on 5	4[illegible]
	2	"	----	1242.0	no	Trees	1 on 5	1 on 4	36
	3	"	1235.8	1243.3	no	Trees	1 on 8	1 on 5	31
	4	"	----	1239.6	no	Grass	1 on 14	1 on 6	26
	5	"	1238.1	1240.0	no	Grass	1 on 4	1 on 4	35
	6	"	1238.1	1241.1	no	Grass	1 on 4	1 on 4	35
	7	"	1238.1	1242.0	no	Grass	1 on 3	1 on 4	35
	8	"	1238.1	1243.0	no	Grass	1 on 4	1 on 5	35
	9	"	1236.2	1242.3	no	Trees	1 on 3	1 on 4	36
	10	"	1236.2	1242.6	no	Brush	1 on 5	1 on 4	39
	11	"	1236.2	1242.6	no	Trees	1 on 4	1 on 4	30
	12	"	----	1243.0	no	Trees	1 on 4	1 on 4	18
	13	"	1236.2	1243.5	no	Trees	1 on 3	1 on 4	36
	14	"	1236.2	1241.5	no	Trees	1 on 8 1 on [illegible]	1 on 2 1 on 4	36
	15	"	1236.0	12[illegible]1.2	no	Trees	1 on 5	1 on 2 1 on [illegible]	48
	16	"	123[illegible].3	1240.9	no	Riprap	1 on 4	1 on 4	32
GULL									
(Main Embankment)	-	1197.7	1198.6	1198.1	yes (0.5 ft.)	Grass	1 on 4	1 on 6	26
LEECH									
(Main Embankment)	-	1297.1	1303.4	1303.4	no	Riprap	1 on 2	1 on 3	28

[1] Freeboard is less than 3 feet.

[2] Location and other pertinent data for this dike is unknown.

Mississippi River Headwaters Lakes - Perimeter Dikes Embankment Characteristics for Freeboard and Erosion Protection Requirements in EC 1110-2-163, ETL 1110-2-221, and ETL 1110-2-222

Lake	Dike No.	Freeboard Reference Level (feet)	Max. Elev. Attained with Design Wave and Required Slope Protection (feet)	Minimum Freeboard Required (feet)	Required Minimum Top of Dike Elevation (feet)	Required Slope Protection for No Erosion of Dikes	Recommended Typical Bottom of Riprap Elevation (feet - 1929 Adj.)	Recommended Top of Riprap Elevation (feet - 1929 Adj.)	Specific Gravity of Riprap Used in Computations	Recommended Riprap Layer Thickness (inches)
SANDY										
(Main Embankment)	1	1226.81	1229.3	3.0	1229.8	Riprap	1221.8	1229.8	2.65	12
	2	"	1228.9	3.0	1229.61	Riprap	1219.2	1229.8	2.65	12
	3	"	1229.0	3.0	1229.91	Riprap	1216.8	1229.8	2.65	12
	4	"	1228.1	3.0	1229.91	Riprap	1221.7	1229.8	2.65	12
POKEGAMA										
(Main Embankment)	-	1277.92	1279.5	3.0	1280.9	Riprap	1264.0	1280.9	2.65	12
	1	"	1280.9	3.0	1280.9	Riprap	1275.5	1280.9	2.65	12
	2	"	1280.9	3.0	1280.9	Riprap	1274.4	1280.9	2.65	12
	3	"	1280.9	3.0	1280.9	Riprap	1273.1	1280.9	2.65	12
	4	"	----	3.0	1280.1	Grass[1]	----	----	--	--
(Roadway near Dike No. 4)	-	"	1279.9	3.0	1280.9	Riprap	1278.2	1280.9	2.65	12
WINNIBIGOSHISH										
(Main Embankment)	-	1304.44	1311.2	3.0	1311.2	Riprap	1296.8	1311.2	2.65	24
	1	"	----	3.0	----	----	----	----	--	--
	2	"	1308.6	3.0	1308.6	Riprap	1299.5	1308.6	2.65	12
	3	"	1308.6	3.0	1308.6	Riprap	1298.3	1308.6	2.65	12
	4	"	1308.6	3.0	1308.6	Riprap	1301.8	1308.6	2.65	12
PINE RIVER (CROSS LAKE)										
(Main Embankment)	-	1234.3	1236.0	3.0	1237.3	Riprap	1232.5	1237.3	2.65	18
	1	"	1236.0	3.0	1237.3	Riprap	1229.0	1237.3	2.65	12
	2	"	----	3.0	1237.3	Grass[1]	----	----	--	--
	3	"	1235.5	3.0	1237.3	Riprap	1231.2	1237.3	2.65	12
	4	"	----	3.0	1237.3	Grass[1]	----	----	--	--
	5	"	1236.2	3.0	1237.3	Riprap	1231.9	1237.3	2.65	12
	6	"	1236.2	3.0	1237.3	Riprap	1230.2	1237.3	2.65	12
	7	"	1236.2	3.0	1237.3	Riprap	1232.0	1237.3	2.65	12
	8	"	1236.2	3.0	1237.3	Riprap	1232.0	1237.3	2.65	12
	9	"	1235.8	3.0	1237.3	Riprap	[illegible]	1237.3	2.65	12
	10	"	1235.4	3.0	1237.3	[illegible]	1231.5	1237.3	2.65	[illegible]
	11	"	1235.8	3.0	1237.3	Riprap	1229.5	1237.3	2.65	12
	12	"	----	3.0	1237.3	Grass[1]	----	----	--	--
	13	"	1235.5	3.0	1237.3	[illegible]	[illegible]	1237.3	2.65	12
	14	"	1235.5	3.0	1237.3	Riprap	[illegible]	1237.3	2.65	12
	15	"	1235.2	3.0	1237.3	Riprap	[illegible]	1237.3	2.65	12
	16	"	1235.2	3.0	1237.3	Riprap	[illegible]	1237.3	2.65	12
GULL										
(Main Embankment)	-	119[illegible]7	1198.6	3.0	[illegible]	Riprap	[illegible]	1200.7	2.65	12
LEECH										
(Main Embankment)	-	1297.1	1300.3	3.0	1300.3	Riprap	[illegible]	1300.3	2.65	12

[1] Existing ground is higher than or approximately at freeboard reference level on lake side of dike.

Mississippi River Headwaters Lakes - Perimeter Dikes Embankment Characteristics for Freeboard and Erosion Protection Requirements in EC 1110-2-163, ETL 1110-2-221, and ETL 1110-2-222 concluded

Lake	Dike No.	Recommended Median Rock Size (pounds)	Recommended Maximum Rock Size (pounds)	Recommended Minimum Rock Size (pounds)	Recommended Dike Side Slope: Lake	Recommended Dike Side Slope: Land	Minimum Top Width Required[2] (feet)	Comments
SANDY								
(Main Embankment)	1	23	92	3	1 on 3	1 on 5	10	
	2	22	88	3	1 on 3	1 on 5	10	
	3	11	44	2	1 on 3	1 on 5	10	
	4	3	12	1	1 on 3	1 on 5	10	
POKEGAMA								
(Main Embankment)	-	8	32	1	1 on 3	1 on 5	10	
	1	30	120	4	1 on 3	1 on 5	10	
	2	30	120	4	1 on 3	1 on 5	10	Roadway nearby could serve as dike. Elevation of roadway is 1282.5
	3	30	120	4	1 on 3	1 on 5	10	Dike is under 24' bituminous road. Elevation 1284.0.
	4	--	--	--	1 on 3	1 on 5	10	Roadway nearby could serve as dike. Elevation of roadway is 1279.2.
(Roadway near Dike No. 4)	-	34	136	5	1 on 3	1 on 5	10	
WINNIBIGOSHISH								
(Main Embankment)	-	300	1200	40	1 on 3	1 on 5	10	
	1	--	--	--	----	----	--	Dike under State Highway No. 2
	2	22	90	3	1 on 3	1 on 5	10	
	3	22	90	3	1 on 3	1 on 5	10	
	4	22	90	3	1 on 3	1 on 5	10	
PINE RIVER (CROSS LAKE)								
(Main Embankment)	-	110	440	14	1 on 5	1 on 5	10	
	1	12	46	1	1 on 5	1 on 5	10	
	2	--	--	--	1 on 5	1 on 5	10	
	3	9	36	2	1 on 8	1 on 5	10	
	4	--	--	--	1 on 14	1 on [illegible]	10	
	5	9	34	1	1 on 4	1 on 5	10	
	6	9	34	1	1 on 4	1 on 5	10	
	7	2[illegible]	[illegible]	3	1 on 3	1 on 5	10	
	8	12	[illegible]	2	1 on 4	1 on 5	10	
	9	22	90	3	1 on 3	1 on 5	10	
	10	10	39	1	1 on 5	1 on 5	10	Dike system has a low point on swale at elevation 1237.5.
	11	9	34	1	1 on 4	1 on 5	10	Dike system has a low point at elevation [illegible]
	12	--	--	--	1 on 4	1 on 5	10	Dike system has a low point at elevation 12[illegible].5 [illegible]
	13	8	32	1	1 on 3	1 on 5	10	
	14	8	32	1	1 on 5	1 on 5	10	
	15	4	15	1	1 on 5	1 on 5	10	
	16	9	34	1	1 on 6	1 on 5	10	
GULL								
(Main Embankment)	-	1	4	1	1 on 4	1 on 8	10	
LEECH								
(Main Embankment)	-	26	104	3	1 on 3	1 on 5	10	

[2] Several dikes have existing top width greater than the required 10 feet. Existing top widths greater than 10 feet exceed the requirements of criteria used in this study. If this condition exists, the larger existing top width may be used but is not necessary for the function of the dikes.

WHITEFISH LAKES CHANNEL OBSTRUCTIONS AND MARKING - PROBLEM 7

Tree stumps and sandbars in connecting channels between the 13 lakes of the Whitefish chain provide a hazard to boats during low water periods such as occurred in 1976. In some cases the connecting channels are very narrow, further complicating the problems of moving a boat from one lake to another.

Alternative 1: No Action

Over 2,200 permanent and seasonal homes and 88 commercial units were located around the 13 Whitefish Lakes in 1977. The Whitefish chain may entertain 40,000 people on a weekend. The chain has a total of 13,000 surface acres and 97 miles of shoreline at normal levels. The 13 lakes are Whitefish, Little Pine, Island, Cross, Daggett, Big Trout, Rush, Bertha, Clamshell, Lower Hay, Arrowhead, Loon, and Pig.

Whitefish Lake is the largest lake in the chain. All 13 lakes are interconnected at normal levels by navigable channels. "Navigable channels" in this instance is more of a legal definition in that some channels are more navigable than others and some can accommodate only shallow-draft craft, such as small motorboats, at normal levels.

The Whitefish Chain Yacht Club, whose principal concern is water safety, annually marks the channels and sandbars, stumps, and other hazards in the Whitefish chain of lakes. Presently, the yacht club uses about 100 marker buoys each year. A Coast Guard Auxiliary unit was formed in 1977 and accepted the responsibility for patrolling the Whitefish chain of lakes. Most members of the auxiliary belong to the yacht club.

Some individual local efforts have been made to clean out connecting channels between the satellite lakes and the main Whitefish Lake. The most recent effort was a 1976 cleanout of the Trout Lake channel which promptly silted in again. The channel apparently filled in rapidly because the material was not disposed of properly and was redeposited by littoral drift and wave action.

Members of the yacht club at one time expressed interest in having the county or U.S. Coast Guard take over full responsibility for patrolling and marking the Whitefish chain. The members believe present marking and patrolling efforts should be expanded and that possibly the county or Coast Guard might best handle the expanded effort.

Some of the natural channel passages from the satellite lakes to the main lake tend to shoal in due to wind and wave action and littoral drift. At least seven lakes have shoaling problems severe enough to cause difficult access and even boat and motor damage for anyone attempting to navigate between the lakes. A significant decrease in property values on the satellite lakes has occurred because guaranteed access to the main Whitefish Lake cannot be maintained. This loss varies from $70 to $90 per foot of shoreline property based on 1973 surveys of lakes in the immediate area (values indexed to October 1981 prices).

The seven lakes that have severe access problems to the main lake and their property value losses are:

Lake	Total shoreline (miles)	Property value loss
Bertha (includes Clamshell)	8.2	$3,030,700
Lower Hay	4.4	1,626,600
Big Trout	8.6	3,178,600
Pig (East Bay)	0.8	295,700
Island	2.6	961,000
Loon	1.2	443,500
Total	25.8	9,536,100

If complete access to the main Whitefish Lake were lost, the property owners on the seven lakes would sustain losses in property values amounting to $9,536,100 based on a $70 per foot decrease.

Alternative 2: Maintain Higher Operating Levels

The majority of lake residents are not interested in higher normal summer operating levels on the Whitefish chain of lakes. The current normal summer levels are from elevation 1229.07 to 1229.57. This operating range was arrived at through public hearings and has been used since the 1940's. Higher normal water levels would cause added flooding and erosion problems for property owners. A cost estimate is not available for this alternative.

Controlling water depths for the seven problem lakes at the minimum desirable summer water level (1229.07) are as follows:

Lake	Controlling depth in feet below elevation 1229.07
Bertha (includes Clamshell)	4.0
Lower Hay	5.3
Big Trout	1.7
Pig (East Bay)	5.5
Island	3.5
Loon	2.0

Corps of Engineers design criteria require a 6-foot depth for recreational navigation, and two of the lakes have nearly adequate depths at the minimum desirable summer water level. However, in years such as 1976, water levels could not be sustained at the normal summer level and were 1.5 feet lower during the recreation season. While the lower operating elevation limit in the lake chain is as low as 1225.32, in a runoff-deficient year the lake levels could reasonably be about 2 feet lower than desired during the recreation season (elevation 1227.07). Alternative 2 is not considered feasible for these reasons.

Alternative 3: Hazard Marking by the U.S. Coast Guard

The U.S. Coast Guard establishes, maintains, and operates aids to navigation when it determines that the aids are necessary for the safety of navigation, useful for commerce (including recreational boating), substantial and permanent in character, and justifiable in terms of public benefit to be derived. The Whitefish chain is not presently served by the U.S. Coast Guard as no such determination has been made. The Coast Guard presently lists the Whitefish Chain of Lakes as navigable for interstate commerce.

The Whitefish Lakes lie within the jurisdiction of the Ninth Coast Guard District, Cleveland, Ohio. This district is presently not staffed or funded to provide the required markings and navigation aids to the Whitefish Lake property owners. The cost of establishing and staffing a Coast Guard station to provide navigation facilities in the Mississippi River Headwaters area could exceed $70,000 annually. This activity could prevent boating accidents but would not solve the problem of keeping the seven lakes open to the main Whitefish Lake.

Alternative 4: Hazard Marking by the County

The Whitefish area property owners have the option of requesting Crow Wing County to mark and patrol the lakes. A county can request money from the State and receive proportional funding for marking and patrolling lakes within its boundaries. The money is collected by the State from boat license fees and is apportioned to counties on the basis of established needs.

This alternative is similar to alternative 3 in that it could prevent boating accidents but would not keep the seven lake connecting channels open to the main Whitefish Lake. This alternative was essentially tried in the summer of 1977 except that the county used Coast Guard auxiliary manpower to patrol the lakes. The cost estimate for this alternative is $45,000 annually.

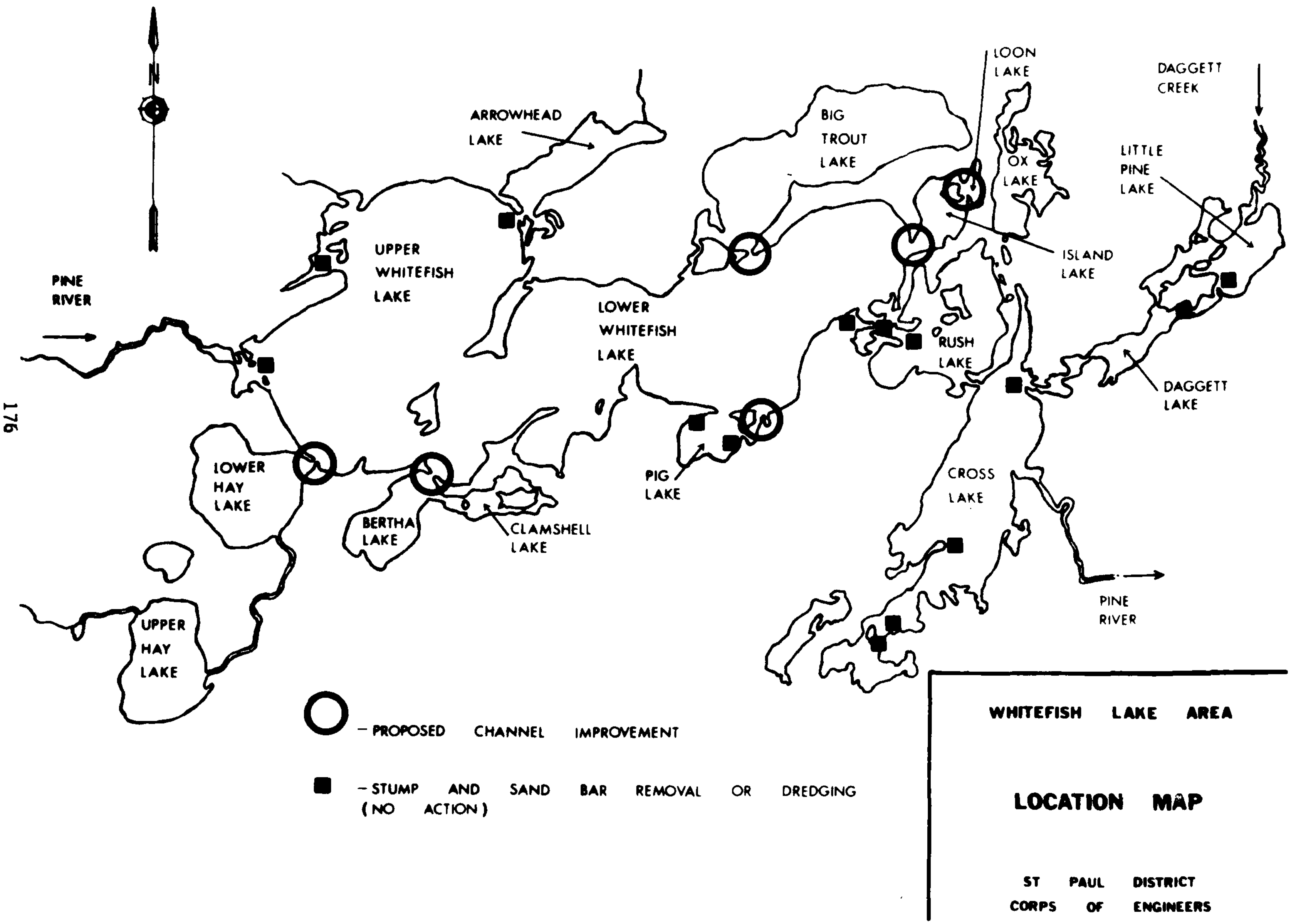
Alternative 5: Stump and Sandbar Removal

This alternative consists of removing sandbars and stumps and dredging at various locations throughout the entire lake chain. No riprap stabilization of inlet channels would be provided. The stump, sandbar, and dredging locations were identified on U.S. Geological Survey maps at an 18 June 1977 meeting of the Whitefish Area Property Owners Association held in Cross Lake, Minnesota. The locations identified at the meeting include the 6 connecting channel locations previously identified and at least 14 additional lake locations.

Local interests have attempted to dredge Big Trout Lake and other connecting channels, but the channels have silted in almost immediately. Therefore, this alternative would require subsequent regular dredging in addition to initial dredging and stump removal. First proposed by Whitefish Lakes residents, the work involved in this alternative does not lie within Corps of Engineers authority.

For comparison, approximate cost and benefit-cost ratio estimates were developed for this alternative. A 6-foot channel with a 75-foot bottom width at water surface elevation 1227.07 for each of the 6 channel inlet locations plus dredging and stump removal at 14 other locations was figured in these estimates. These design criteria originate from a U.S. Army Corps of Engineers Special Report No. 2, Design, Construction and Operation of Small-Craft Harbors. The report recommends a minimum channel depth of 6 feet and a width of five times the width of the widest boat using the area. The 75-foot width provides for sailboats using the channel also. The first cost of this alternative is $2,176,800; the benefit-cost ratio is 3.35.

This alternative shows a favorable benefit-cost ratio, but it would not be feasible because of the limited jurisdiction of the Corps of Engineers in unrestricted lake dredging at regular intervals. It would be feasible and within the Corps responsibility to construct only the six lake inlet channels identified in alternative 2. This project is evaluated in alternative 6. Alternative 5 is shown on the following figure.


N
PINE
RIVER
ARROWHEAD
LAKE
UPPER
WHITEFISH
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LOWER
WHITEFISH
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BIG
TROUT
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LOON
LAKE
OX
LAKE
ISLAND
LAKE
DAGGETT
CREEK
LITTLE
PINE
LAKE
DAGGETT
LAKE
RUSH
LAKE
CROSS
LAKE
PINE
RIVER
PIG
LAKE
LOWER
HAY
LAKE
BERTHA
LAKE
CLAMSHELL
LAKE
UPPER
HAY
LAKE
– PROPOSED CHANNEL IMPROVEMENT
– STUMP AND SAND BAR REMOVAL OR DREDGING
(NO ACTION)
WHITEFISH LAKE AREA
LOCATION MAP
ST PAUL DISTRICT
CORPS OF ENGINEERS

Alternative 6: Construct 75-Foot Permanent Channels

This alternative would involve construction of a 6-foot-deep channel at elevation 1227.07 (2 feet below the minimum summer operating level) in each of the six channel inlet locations identified in alternative 2. The channels between the six satellite lakes and the main Whitefish Lake would be widened to 75 feet (bottom width) with 1V to 3H side slopes. Riprap jetties would be placed on each side of the excavated channels and the channel dredged material would be placed on the outside or landward side of the jetties.

The first cost of this alternative is $1,772,700, and the combined benefit-cost ratio is 2.48. The channel sites are shown on the figure on page 173. A cost summary by individual lake site is shown in the following table; however, the plan is not acceptable as two of the sites are not economically feasible.

Alternative 6 - comparison of costs and benefits

Lake site[1]	First cost	Annual cost	Annual benefit	Benefit-cost ratio
Bertha	$245,000	$31,400	$177,750	5.66
Lower Hay	233,700	25,600	95,400	3.73
Big Trout	255,500	35,000	186,525	5.33
Pig (East Bay)	298,000	33,300	14,700	0.44
Island	251,000	30,200	56,325	1.87
Loon	489,500	67,000	22,000	0.33
Total	1,772,700	222,500	552,700	2.48

(1) Design water surface is 1227.07 with clamshell dredging and 75-foot channel bottom at each location.

Alternative 7: Construct 40-Foot Permanent Channels

This alternative is identical to alternative 6 except that a channel bottom width of 40 feet would be used at all six sites. A majority of Whitefish Lakes property owners surveyed on 18 June 1977 appeared to favor the 40-foot width. (The survey responses suggested 25- to 150-foot proposed channel widths.)

The first cost of this alternative is $1,170,900 and the benefit-cost ratio is 3.46. A cost summary by individual lake site is shown in the following table.

Alternative 7 - comparison of costs and benefits

Lake site(1)	First cost	Annual cost	Annual benefit	Benefit-cost ratio
Bertha	$225,100	$25,000	$150,100	6.00
Lower Hay	221,200	20,900	80,500	3.85
Big Trout	236,900	28,000	157,600	5.63
Pig (East Bay)	94,600	13,400	14,700	1.10
Island	242,500	26,800	47,500	1.77
Loon	150,600	22,400	22,000	0.98
Total	1,170,900	136,500	472,400	3.46

(1) Forty-foot bottom width channels and six-foot depths at water surface elevation 1227.07 with clamshell dredging.

Alternative 8: Construct 40- and 75-Foot Permanent Channels

This alternative would involve construction of a 6-foot-deep, 75-foot-wide channel at elevation 1227.07 for the four lakes that show economic feasibility for this proposal. The alternative would include only a 40-foot-wide bottom in the remaining two lakes - Pig Lake (East Bay) to Whitefish Lake, and Island Lake to Loon Lake. The 40-foot bottom width would provide an economically feasible project at these two locations also.

The first cost of this alternative is $1,230,300 and the benefit-cost ratio is 2.99. A cost summary by individual lake is shown in the following table.

Alternative 8 - comparison of costs and benefits

Lake site(1)	First cost	Annual cost	Annual benefit	Benefit-cost ratio
Bertha	$245,000	$31,400	$150,100	4.78
Lower Hay	233,600	25,600	80,500	3.14
Big Trout	255,500	35,000	157,600	4.50
Pig (East Bay)	94,600	13,400	14,700	1.10
Island	251,000	30,200	47,600	1.58
Loon	150,600	22,400	22,000	0.98
Total	1,230,300	158,000	472,500	2.99

(1) Seventy-five foot bottom width channels except for Pig (East Bay) and Loon Lakes, which are 40-foot bottoms. Design water surface equals 1227.07 with clamshell dredging.

Review of Alternatives

Cost data for the structural and nonstructural alternatives are summarized in the following table.

Whitefish Lakes channels - comparison of costs and benefits of alternatives

Alternative	First cost	Annual cost(1)	Annual benefit(2)	Benefit-cost ratio
1. No action	-	-	-	-
2. Higher operating levels	-	Not available	-	-
3. Hazard marking by U.S. Coast Guard	-	$70,000	-	-
4. Hazard marking by county	-	$45,000	-	-
5. Stump and sandbar removal (channels 75-foot bottom)	$2,176,800	188,300	$630,100	3.35
6. Permanent channels (75-foot bottom)	1,772,700	222,500	472,400	2.12
7. Permanent channels (40-foot bottom)	1,170,900	136,500	472,400	3.46
8. Permanent channels (40- and 75-foot bottom)(3)	1,230,300	158,000	472,500	2.99

(1) Includes all operation and maintenance costs.
(2) Fifty-year life and 7 5/8-percent interest.
(3) Four 75-foot and two 40-foot channel bottoms.

Alternatives Considered Further

Alternatives 1, 3, 4, 6, 7, and 8 were considered further. Alternatives 1, 3, and 4 are nonstructural alternatives and alternatives 6, 7, and 8 involve structural measures. Alternative 1 would not improve lake conditions. Alternatives 3 and 4 offer only partial protection to boating interests and would not prevent economic losses. Alternative 6 provides a permanent solution to the channel access problems for lake property owners and meets Corps design criteria for small-boat access. However, two of the six sites are not individually economically feasible with this alternative. Alternative 7 also provides a permanent solution to the channel access problem but with a lesser channel width than alternative 6. This channel width is more acceptable to lake property owners and each project site is economically feasible. Alternative 8 provides a permanent solution to channel access. This alternative uses a 75-foot bottom width channel where economically feasible. Otherwise, a 40-foot economically feasible channel is used.

Contribution to Alternatives to Specific Planning Objectives

The following table ranks the alternatives according to their contributions to specific planning objectives; alternative 7 rates highest.

Specific planning objective	Rating of alternatives — Plan satisfaction rating: High							Low
Economic feasibility	Alternative 1	Alternative 7	Alternative 8	Alternative 6	Alternative 5	Alternative 4	Alternative 3	Alternative 2
Preserve and enhance the quality of the environment	Alternatives 1, 3, and 4		Alternative 7	Alternative 8	Alternative 6	Alternative 5		Alternative 2
Enhance economic welfare of the basin population	Alternatives 6, 7, and 8		Alternative 5	Alternative 3	Alternative 4	Alternative 1		Alternative 2
Minimum disruption to man-made or natural resources	Alternatives 1, 3, and 4		Alternative 7	Alternative 8	Alternative 6	Alternative 5		Alternative 2
Social acceptability	Alternative 5	Alternative 7	Alternative 8	Alternative 6	Alternative 3	Alternative 4	Alternative 1	Alternative 2
Local cooperation	Alternative 5	Alternative 7	Alternative 8	Alternative 6	Alternative 3	Alternative 4	Alternative 1	Alternative 2

Alternative 1: No action.
Alternative 2: Higher operating levels.
Alternative 3: Hazard marking by U.S. Coast Guard.
Alternative 4: Hazard marking by Crow Wing County.
Alternative 5: Stump and sandbar removal.
Alternative 6: Permanent channels (75-foot bottom).
Alternative 7: Permanent channels (40-foot bottom).
Alternative 8: Permanent channels (40- and 75-foot bottom).

Contribution of Alternatives to National Objectives

The contribution made by each alternative to the two national objectives of economic development and environmental quality must be evaluated. The Principles and Standards require that a national economic development plan and an environmental quality plan be identified.

The national economic development plan is that plan which maximizes net economic benefits while addressing the range of planning objectives. National economic benefits are determined by measuring and analyzing the net value of increases in goods and services derived from the plan. The national economic development plan is alternative 7.

An environmental quality plan must make a net beneficial contribution to environmental values while addressing the planning objectives. No environmental quality plan could be identified, although alternatives 3 and 4 would have the least environmental impact. The following table summarizes the environmental impacts of each alternative.

Effects of alternatives on physical impact area

Environmental quality item	Alternative 1 No action	Alternative 2 Higher operating levels	Alternative 3 Hazard marking by U.S. Coast Guard	Alternative 4 Hazard marking by Crow Wing County	Alternative 5 Stump and sand-bar removal	Alternative 6 75-foot bottom permanent channels	Alternative 7 40-foot bottom permanent channels	Alternative 8 40- and 75-foot permanent channels
Wild and scenic rivers	0 No change	0 No change	0 No change	0 No change	0 No change	0 No change	0 No change	0 No change
Natural streams	0 No change	0 No change, existing reservoir	0 No change	0 No change	0 No change, existing reservoir	0 No change, existing reservoir	0 No change, existing reservoir	0 No change, existing reservoir
Beaches	+1 Gradual increase	-2 Major loss	+1 Gradual increase	+1 Gradual increase	0 No change	-1 Minor loss	-1 Minor loss	-1 Minor loss
Archeological-historical	0 No change	-2 Would adversely affect six known sites	0 No change	0 No change	[illegible] No change	-2 Would affect five known sites	-2 Would affect five known sites	-2 Would affect five known sites
[illegible]	0 No change	0 No known effect	0 No change	0 No change	0 No known effect	0 No known effect	0 No known effect	0 No known effect
Aesthetic values	-1 Gradual loss in aesthetic values from shoaling	0 Questionable gain or loss - no change	-1 Gradual loss in aesthetic values from shoaling	-1 Gradual loss in aesthetic values from shoaling	-2 Required frequent maintenance will cause significant loss	+1 Minor initial loss caused by construction. Overall effect is good	+1 Minor initial loss caused by construction. Overall effect is good	+1 Minor initial loss caused by construction. Overall effect is good.
Urban open space	0 No change	0 No change	0 No change	0 No change	0 No change	0 No change	0 No change	0 No change
Land quality	0 No change	-2 Major erosive effects on adjoining lands	0 No change	0 No change	-1 Minor loss for disposal areas	-1 Minor loss for disposal areas	-1 Minor loss for disposal areas	-1 Minor loss for disposal areas
Recreation	-2	+1 Improved recreation	+1 Improved recreation	+1 Improved recreation	+1 Improved recreation	+2 Improved recreation	+2 Improved recreation	+2 Improved recreation
Air quality and noise	0 No change	0 No change	0 No change	0 No change	-2 Adverse effect during construction	-1 Adverse effect during construction	-1 Adverse effect during construction	-1 Adverse effect during construction
Streambank erosion	-1 Continued moderate bank erosion	-2 Severe bank erosion	-1 Continued moderate bank erosion	-1 Continued moderate bank erosion	-1 Continued moderate bank erosion	-1 Continued moderate bank erosion	-1 Continued moderate bank erosion	-1 Continued moderate bank erosion
Water quality	0 No change	-2 Increased turbidity from bank erosion	0 No change	0 No change	-2 Increased turbidity during construction, long term	-1 Increased turbidity during construction, short term	-1 Increased turbidity during construction, short term	-1 Increased turbidity during construction, short term
Biological resources	0 No change	0 No known effect	0 No known effect	0 No known effect	-2 Long-term detrimental effect	-1 Minor short-term detrimental effect	-1 Minor short-term detrimental effect	-1 Minor short-term detrimental effect
Rare and endangered species	0 No known effect	0 No known effect	0 No known effect	0 No known effect	0 No known effect	0 No known effect	0 No known effect	0 No known effect
Ecological systems								
Terrestrial	0 No change	-1 Minor adverse effect	0 No change	0 No change	0 No change	0 No change	0 No change	0 No change
Aquatic	[illegible] No change	-2 Major adverse effect	0 No change	0 No change	-2 Long-term effect	-1 Short-term minor effect	-1 Short-term minor effect	[illegible] Short-term minor effect
Preservation of freedom of choice for future resource use	[illegible] No change	-2 Major adverse effect on future choice	0 No change	0 No change	+1 Possible future choice	-1 No freedom for future choice	-1 No freedom for future choice	0 No freedom for future choice
Totals	− = 4 [illegible] + = 1	− = [illegible] 0 = 8 + = [illegible]	− = 2 0 = [illegible] + = 2	− = 2 0 = [illegible] + = 2	− = 12 0 = [illegible] + = 2	− = [illegible] 0 = 6 + = 3	− = [illegible] 0 = 6 + = 3	− = [illegible] 0 = [illegible] + = 3

Key:

-2 = Significant loss or long-term effect.
-1 = Slight loss or short-term effect.
0 = Status quo.
+1 = Slight gain or short-term effect.
+2 = Significant gain or long-term effect.

Discussion

The Whitefish Chain Yacht Club and the Whitefish Lake Property Owners Association both support cleanout and permanent facilities to provide improved access to Big Trout and other perimeter lakes. However, construction of the required facilities, which would improve recreational use in the lakes, would require a local sponsor to provide 50 percent of the project first costs.

Local interests believe the required Corps design standards are too stringent and would lead to too large a cost for local participation. The local interests could spend less money working on their own by constructing inlet channels similar in size to the one that presently connects Arrowhead Lake to Upper Whitefish Lake (10-foot bottom with 3H to 1V side-slopes). A good number of the local group believe the 75-foot-wide and even the compromise 40-foot-wide channels recommended by the Corps are too large.

Neither Crow Wing County nor the State of Minnesota is interested in being a local sponsor for this project. Although the State originally constructed the Arrowhead access for fish spawning purposes in 1960, it maintains that none of the lakes currently proposed for improved access would provide a similar useful objective.

Cultural Resources

The Corps has conducted cultural resource surveys in the Whitefish Lake chain. These surveys have identified numerous significant prehistoric sites. Any action taken to implement any proposed solution to this problem may have an impact on cultural resources, particularly alternatives 6, 7, and 8 which include channel widening. These alternatives may affect five known prehistoric sites.

Prior to implementation, additional surveys and testing will need to be conducted within the project area. All sites located within the area that may be affected by the proposed project will need to be tested to determine their significance. All significant sites listed on or eligible for inclusion on the National Register of Historic Places will need to be mitigated in accordance with Advisory Council on Historic Preservation regulations, 36 CFR 800, prior to construction.

Recommendations

Because no authorized sponsor has agreed to support this proposal, the project is not recommended for further study. If a local sponsor is found at a later date, the general alternative of construction of channels should be evaluated further under the small project authority. Under this authority, a detailed project report for construction could be prepared for the approval of the Chief of Engineers. An environmental assessment would also be prepared at that time. If required, an environmental impact statement and 404(b)(1) evaluation of the placement of dredged and/or fill material would be conducted in lieu of or subsequent to the assessment.

LEECH LAKE DAM INLET CHANNEL RESTRICTIONS - PROBLEM 8

A physical problem occurs when flows in the 1,000-cfs range are released from the Leech Lake Dam while the lake is at or below summer pool level 1294.9. A differential of about 1 foot develops in the approach channel between the lake and the water surface at the control structure. This problem is the result of several factors: (1) sediment buildup at the inlet entrance, (2) floating bogs that drift into the inlet, and (3) aquatic vegetation growing in the inlet. The problem is particularly acute when Leech Lake needs to be lowered during the fall and winter to provide flood storage for the next spring.

Alternative 1: No Action

Inability to release flows in the 1,000-cfs range during critical periods can cause increased water levels and greater damage in Leech Lake than would occur with the greater dam outlet capacity. The existing annual expenditure of about $1,300 to remove bogs floating in the Leech Lake inlet would continue. However, bog removal would not solve the problem of providing adequate outlet capacity during critical periods. Field surveys show that since 1912 the Leech Lake inlet has silted in possibly as much as 4 feet in places. The main channel has moved northeastward and has two major humps or blockages in reaches 1,000 to 5,000 and 9,000 to 13,200 feet upstream of Leech Lake Dam.

Alternative 2: Dredging

This alternative would involve removing approximately 186,000 cubic yards of sand and silt from the established Leech Lake inlet channel. Approximately 161,000 cubic yards would be removed from the channel portion of the inlet, and 25,000 cubic yards would be removed in the lake portion of the inlet. The dredged material would be placed in a 40-acre diked disposal area near the lake inlet. Actual work would involve dredging the present channel to a 100-foot bottom width and 1V to 4H side slopes for a distance of 13,200 feet upstream from the Leech Lake Dam. The channel depth would be 8.7 feet at normal summer pool level 1294.7 and would provide 1,000-cfs flow at a water level 1 foot lower (1293.7). The Leech Lake inlet channel has never been dredged before.

The first cost of this alternative is $1,173,800; the benefit-cost ratio is 2.09.

Alternative 3: Aquatic Weed Control

Aquatic weed control involves a number of new methods currently under investigation to control weeds. This alternative is divided into (1) chemical control and (2) mechanical harvesting because these two methods could be used successfully at the Leech Lake inlet location.

Alternative 3a: Chemical control - This alternative would involve using herbicides to control approximately 50 acres of aquatic growth, primarily wild rice, in the nearly 400-acre Leech Lake inlet channel. The vegetation growth in a 170-foot wide area extending 13,200 feet upstream from Leech Lake Dam would be sprayed up to twice annually to prevent weed growth in the existing 50- to 200-foot wide inlet channel.

Control of the aquatic growth in this manner would not restore the desired 1,000-cfs channel capacity but could possibly provide 30 percent of the desired improvement. The annual cost of this alternative is $4,700, with a first cost of $61,500 based on a 50-year application period and a 7 5/8-percent interest rate.

This alternative has a favorable benefit-cost ratio of 8.5, but offers only a partial solution to the inadequate flow capacity of the Leech Lake inlet. Most of the desired 170-foot channel width is already vegetation free.

Alternative 3b: Mechanical harvesting - This alternative would involve removal of growth by mechanical harvesting twice a year. Vegetation would be cut 4 feet below the water surface, loaded on an accompanying barge, and transferred to a truck for disposal at a convenient landfill disposal site. This alternative has a first cost of $426,100, with an annual cost of $32,500 and a benefit-cost ratio of 1.23.

This alternative has a rather high initial investment cost for equipment and disposal. The benefits are identical to those in alternative 3a; similarly, alternative 3b provides only a partial solution.

Review of Alternatives

Cost data for the structural and nonstructural alternatives are summarized in the following table.

Comparison of costs and benefits

Alternative	First cost	Annual cost[1]	Annual benefit	Benefit-cost ratio
1. No action	-	$1,300	0	-
2. Dredging	$1,173,800	91,800	$191,600[2]	2.09
3. Aquatic weed control:				
a. Chemical	61,500	4,700	40,000	8.5
b. Mechanical	426,100	32,500	40,000	1.23

(1) Operation and maintenance costs are negligible.
(2) Based on lowering Leech Lake annual high water level approximately 0.6 foot.

Alternatives Considered Further

Alternatives 1, 3a, and 3b are considered nonstructural options; alternative 2 is a structural approach. All alternatives except alternative 1, no action, have a favorable benefit-cost ratio. The alternatives are compared in the following paragraphs.

Contribution of Alternatives to Specific Planning Objectives

The following table ranks the alternatives according to their contributions to specific planning objectives; alternative 2 rates the highest.

Rating of alternatives

Specific planning objectives	Plan satisfaction rating: High			Low
Economic feasibility	Alternative 3a	Alternative 2	Alternative 3b	Alternative 1
Preserve and enhance the quality of the present area environment	Alternative 1	Alternative 3b	Alternative 2	Alternative 3a
Enhance economic welfare of the basin population	Alternative 2	Alternative 3b	Alternative 3a	Alternative 1
Minimum disruption to man-made or natural resources	Alternative 1	Alternative 3b	Alternative 3a	Alternative 2
Social acceptability	Alternative 2	Alternative 3b	Alternative 3a	Alternative 1
Local cooperation	Alternative 2	Alternative 3b	Alternative 3a	Alternative 1

Alternative 1: No action.
Alternative 2: Dredging.
Alternative 3: Aquatic weed control.

a. Chemical.
b. Mechanical harvesting.

Contribution of Alternatives to National Objectives

The contribution made by each alternative to the two national objectives of economic development and environmental quality must be evaluated. The Principles and Standards require that a national economic development plan and an environmental quality plan be identified. Normally a nonstructural plan is also identified; in this case the nonstructural plans are alternatives 1, 3a, and 3b.

The national economic development plan is that plan which maximizes net economic benefits while addressing the range of planning objectives. National economic benefits are determined by measuring and analyzing the net value of increases in goods and services derived from the plan. The national economic development plan is alternative 2.

An environmental quality plan must make a net contribution to environmental values while addressing the planning objectives. No environmental quality plan could be identified. The following table summarizes the environmental impacts of each alternative.

Effects of alternatives on physical impact area

Environmental quality item	Alternative 1 No action	Alternative 2 Dredging	Alternative 3a Chemical control	Alternative [illegible] Mechanical harvesting
Wild and scenic rivers	0 - No change.	0 - No change.	0 - No change.	0 - No change.
Natural streams	0 - No change.	-1 - Moderate effect on stream, particularly during dredging.	-1 - Moderate effect on stream during application.	0 - No measurable effe
Beaches	0 - No change.	+1 - Dredged material could provide beach area.	0 - No beach area affected.	0 - No beach area affected.
Archeological historical	0 - No change.	0 - No known effects.	0 - No change.	0 - No change.
Social	0 - No change.	0 - No known effect.	0 - No known effect.	0 - No known eff[illegible].
Aesthetic values	0 - No change.	-1 - Unsightly conditions during construction; affects disposal site.	-1 - Vegetation die-off is unsightly.	0 - No known effect.
Open space	0 - No change.	0 - No change.	0 - No [illegible].	0 - No change.
Land quality	0 - No change	+1 - Minor improvement to land area from disposal.	0 - No change.	-1 - Minor loss for required disposal area.
Recreation	0 - No change.	+2 - Improved recreation with beach construction and improved lake access.	+1 - Minor improvement in lake access.	+1 - Minor improvement in lake access.
Air quality and noise	0 - No change.	-1 - Minor and short-term pollution because of construction.	0 - No measurable impact.	-1 - Minor and short-term due to harvesting and disposal of weeds.
Streambank erosion	0 - No change.	0 - No change.	0 - No change.	0 - No change.
Water quality	0 - No change	-1 - Minor adverse effect during dredging.	-2 - Major effect in limited area.	+1 - Improvement with plant nutrient removal.
Biological resources	0 - No change	-1 - Minor eff[illegible].	-2 - Major effect in limited area.	0 - No measurable eff[illegible].
Rare and endangered species	0 - No change.	0 - No known effect.	0 - No known effect.	0 - No known effect.
Ecological systems				
Terrestrial	0 - No change.	0 - No change.	0 - No change.	0 - No change.
Aquatic	0 - No change.	-1 - Up to 5 acres of aquatic growth removed permanently.	-1 - Up to 5 acres of aquatic growth removed twice annually.	-1 - Up to 5 acres of aquatic growth removed twice annually.
Preservation of freedom of choice for future resource use	+1	-1	+1	+1
Totals	- = 0 0 = 16 + = 1	- = 7 0 = 7 + = 4	- = 7 0 = 10 + = 2	- = 3 0 = 11 + = 3

Key: -2 = Significant loss or long-term effect.
-1 = Slight loss or short-term effect.
0 = Status quo.
+1 = Slight gain or short-term effect.
+2 = Significant gain or long-term effect.

Summary of Alternatives

The principal goal of these alternatives is to restore adequate outflow capacity from Leech Lake to the Leech Lake Dam. Restoring flow capacity would allow fall and winter drawdowns to be more effective so that more flood storage space would be available in the spring. This need is particularly evident during periods such as the fall and winter of 1977-78.

Alternative 2 (dredging) is the only alternative which meets the specific planning objectives. It is also the best national economic development plan and would not cause major adverse environmental impacts. Plan 3b (mechanical harvesting) is a better environmental quality plan but offers only a partial solution to the overall problem.

The size of the channel cleanout was selected to provide the required flow capacity for winter drawdown (1,000 cfs) without grossly affecting the ecological system. Most of the required dredging would be in the vicinity of the lake where shoaling of the inlet is the heaviest. Only limited dredging is required in the remaining portion of the inlet channel. Also, the channel dredging would follow the existing channel alignment so as to cause only minimal disruption to the environment. The location of this alternative is shown on the photograph on page 73.

Cultural Resources

The headwaters lakes region contains numerous significant prehistoric and historic sites. The Corps has conducted surveys to identify these sites in some areas of the headwaters region. But not all sites in the area have been located. Any action taken to implement any proposed solution to this problem may have an impact on cultural resources, particularly those that may involve dredging and dredged material placement as in alternative 2.

Prior to implementation, additional surveys will need to be conducted within the project area. All sites located within the area that may be affected by the proposed project will need to be tested to determine their significance. All significant sites listed on or eligible for inclusion on the National Register of Historic Places will need to be mitigated in accordance with Advisory Council on Historic Preservation regulations, 36 CFR 800, prior to construction.

Recommendations

The Minnesota Department of Natural Resources requires permits of the public for work that will change the course, current, or cross section of public waters. Corps of Engineers policy is to obtain State permits only for activities involving maintenance dredging for navigation.

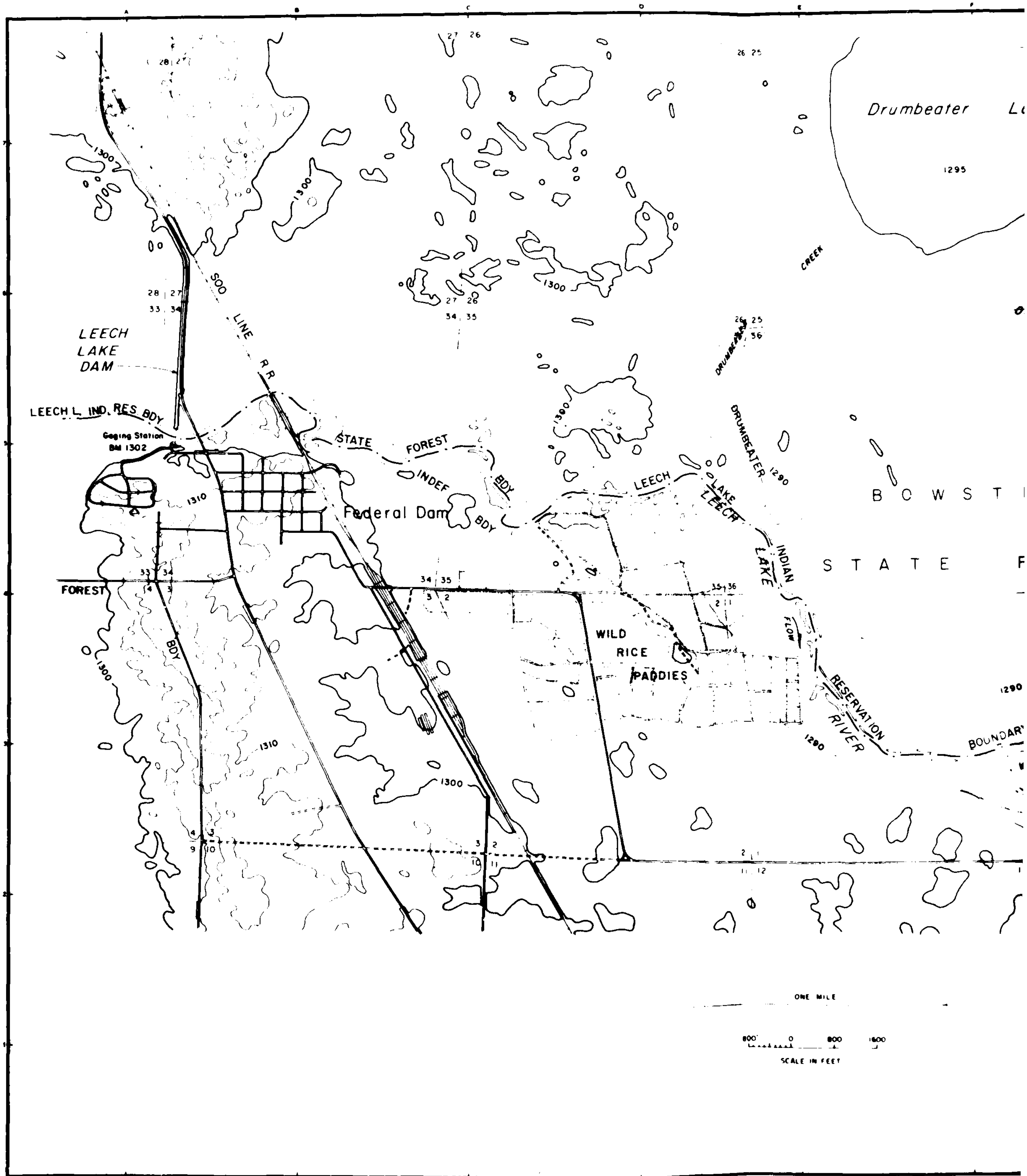
Whether the project will require a State permit is not certain at this time. However, it will be necessary to coordinate closely with the State of Minnesota on the proposed Leech Lake inlet dredging to select suitable disposal sites. An environmental assessment done under operations and maintenance authority would be required before any of these alternatives could be implemented. A 404(b)(1) evaluation may be required for the disposal of dredged material.

Alternative 2 (dredging) will not be studied further under the Mississippi River Headwaters authority. Channel dredging can be implemented under the District's continuing operation and maintenance program. Operation and maintenance funding for this work is not currently scheduled.

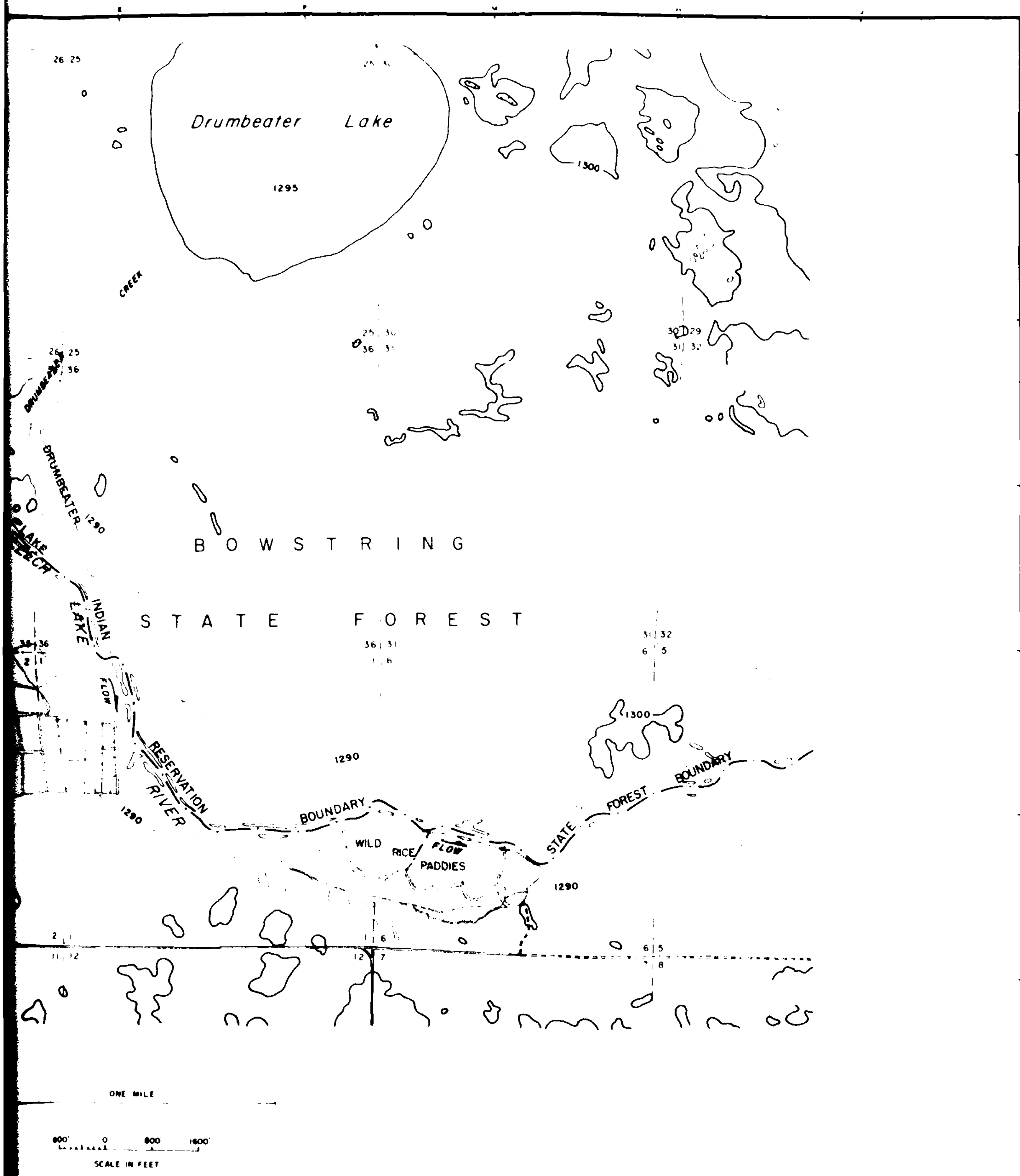
LEECH LAKE MARSH CHANNEL CUTOFFS - PROBLEM 9

The Corps of Engineers completed channel improvements including straightening and closing of auxiliary channels in the areas below Leech Lake and Winnibigoshish Dams during the period 1914 to 1926. This construction was undertaken to provide a more efficient flow of water to Pokegama Lake Dam and for downstream navigation below Minneapolis.

Wild rice production and fish and wildlife resources were lost because of the channel work. The U.S. Fish and Wildlife Service originally proposed that the marsh area downstream of Leech Lake Dam be restored and managed for wildlife and wild rice production. Existing conditions in the 4-mile reach downstream of Leech Lake Dam are shown on the following figure.



Drumbeater L
1295
CREEK
SOO LINE R R
LEECH LAKE DAM
LEECH L. IND. RES BDY
Gaging Station
BM 1302
STATE FOREST INDEF BDY
Federal Dam
DRUMBEATER
1290
LEECH LAKE
LEECH LAKE INDIAN
B O W S T
S T A T E F
FOREST BDY
WILD RICE PADDIES
FLOW
RESERVATION BOUNDARY
RIVER
1300
1310
1307
ONE MILE
800 0 800 1600
SCALE IN FEET



LEECH LAKE RIVER

EXISTING CONDITIONS

ST PAUL DISTRICT CORPS OF ENGINEERS

U.S.GPO:1979-665-155/58-6

Alternative 1: No Action

The low-lying lands bordering the Leech Lake River downstream of Leech Lake Dam are essentially dry marsh. These lowlands do not support agriculture, forestry, or other economic activities except for some recent rice paddy developments on the south or right bank of the river. Access to the area is principally by boat or canoe.

The area has remained virtually untouched since the 1914 to 1926 channeling. The operation of Pokegama Lake does not adversely affect this area because the Pokegama Lake flowage levels are separated from this area by the existing Mud Lake Dam originally constructed by the State of Minnesota and operated by the Corps of Engineers under agreement with the State.

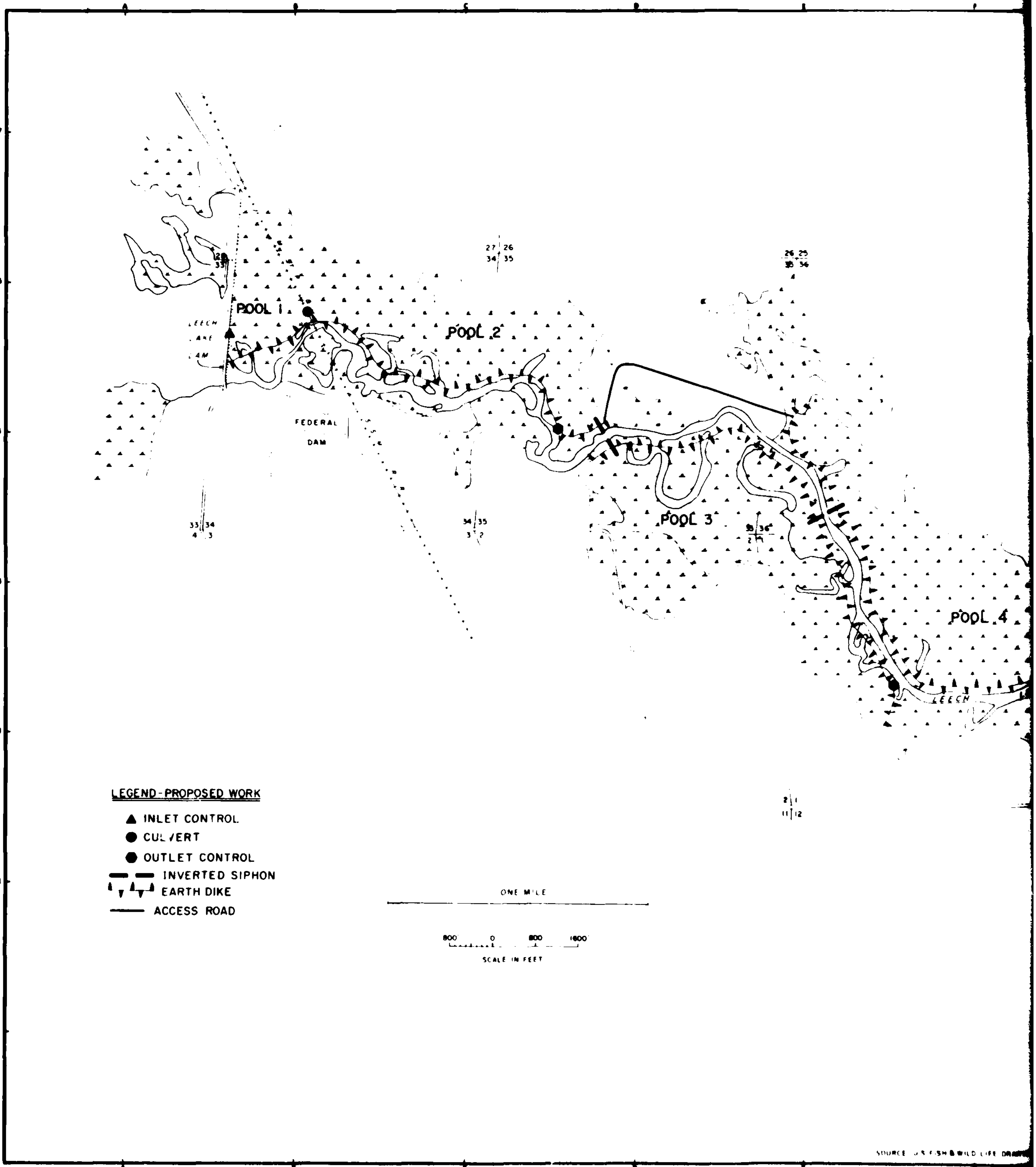
The no action alternative would not cause serious problems in the area. This alternative is presently favored by the U.S. Forest Service which is proposing the Leech Lake River as a canoe route in its land use planning for the area. Most of the land along both sides of the Leech Lake River is State or national forest land and lies within the overall Chippewa National Forest boundary. This section of the river is not proposed for inclusion as a part of the Wild and Scenic Rivers System.

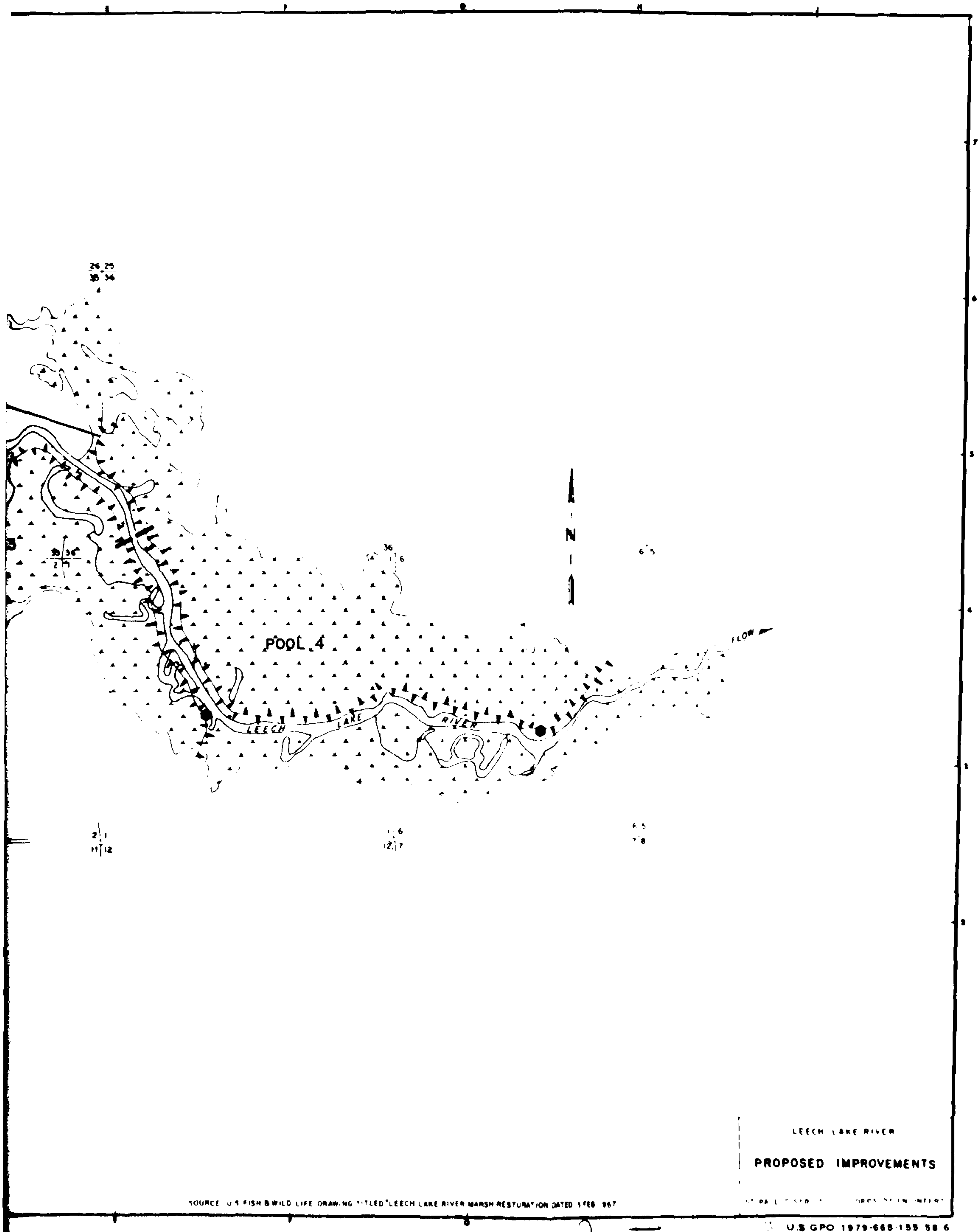
Alternative 2: Construct Side Channel Impoundments

This alternative would involve construction of four side channel impoundments or ponds along the Leech Lake River downstream from the Leech Lake Dam. The ponds would be located in a section of the river about 4 miles below the Leech Lake Dam. Existing banks of dredged material from the 1914-1926 channel straightening would provide a portion of the diking needed to impound water for waterfowl production and migration, furbearers, and wild rice production. Additional dike material would be obtained from side borrow on the inside of the dike locations.

Water for the four impoundments (totaling about 1,050 surface acres) would be obtained through a new control gate in the Leech Lake Dam. Water would be released directly into the first pond, and each of the three downstream ponds would receive water successively from the pond immediately upstream by means of gated culverts or inverted siphons. Two inverted siphons would carry water back and forth underneath the Leech Lake River between ponds 2 and 3 and between ponds 3 and 4. Each pond would be able to release directly to the Leech Lake River through a gated culvert.

This alternative has a first cost of $1,711,000 and an unfavorable benefit-cost ratio of 0.51. The alternative in shown on the following figure.

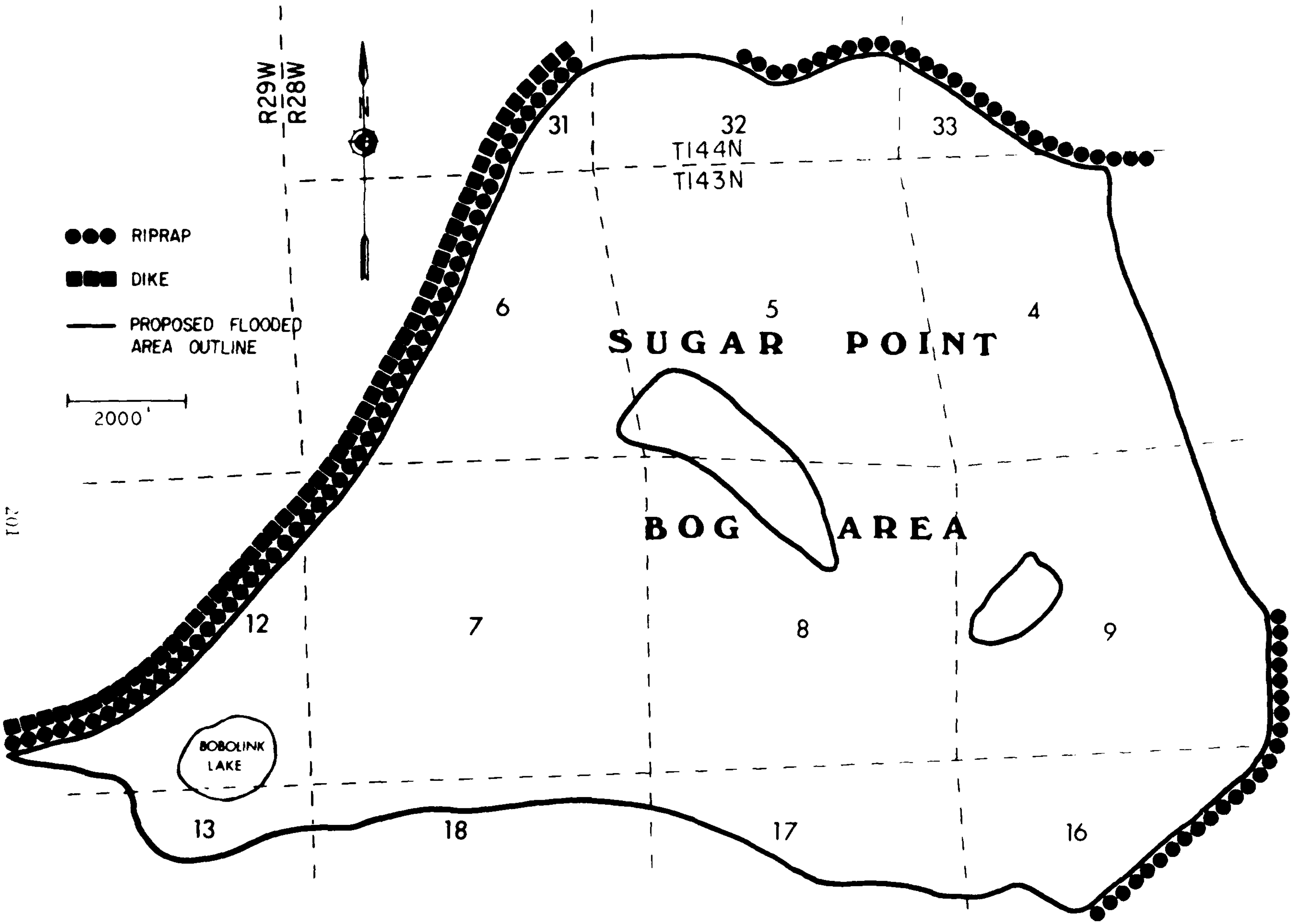

POOL 1
POOL 2
POOL 3
POOL 4
LEECH LAKE DAM
FEDERAL DAM
LEECH
27 26
34 35
26 25
35 36
33 34
4 3
34 35
3 2
35 36
2 1
11 12
LEGEND - PROPOSED WORK
INLET CONTROL
CULVERT
OUTLET CONTROL
INVERTED SIPHON
EARTH DIKE
ACCESS ROAD
ONE MILE
800 0 800 1600
SCALE IN FEET
SOURCE U.S. FISH & WILD LIFE


POOL 4
LEECH LAKE RIVER
FLOW
N
LEECH LAKE RIVER
PROPOSED IMPROVEMENTS
SOURCE U.S. FISH & WILD LIFE DRAWING TITLED "LEECH LAKE RIVER MARSH RESTURATION" DATED 5 FEB 1967

Alternative 3: Leech Lake Subimpoundments

This alternative was discussed earlier as an alternative to the construction of a dam across the Mississippi River at Days High Landing. The purpose of the Days High Landing Dam would be to stabilize about 6,300 acres of marsh subject to fluctuation because of Pokegama Lake operation. The Leech Lake subimpoundment identified previously as the Sugar Point bog area typifies this type of development. About 4,030 acres of bog would be required to develop 2,800 acres of water levels for wild rice production and fish and wildlife enhancement.

The Leech Lake Sugar Point bog subimpoundment has a first cost of $2,002,800. The plan is not economically feasible with a benefit-cost ratio of 0.85. This alternative is shown on the following figure.


RIPRAP
DIKE
PROPOSED FLOODED AREA OUTLINE
2000'
R29W
R28W
N
T144N
T143N
SUGAR POINT
BOG AREA
BOBOLINK LAKE
31
32
33
6
5
4
12
7
8
9
13
18
17
16

Review of Alternatives

Cost data for the structural and nonstructural alternatives are summarized in the following table.

Comparison of costs and benefits

Alternative	First cost	Annual cost (1)	Annual benefit	Benefit-cost ratio
1. No action	-	-	-	-
2. Side channel impoundments	$1,711,000	$140,500	$71,400	0.51
3. Leech Lake subimpoundments (Sugar Point bog)	2,002,800	246,600	210,000	0.85

(1) Includes operation and maintenance costs. Based on 50-year project life and 7 5/8-percent interest.

Contribution of Alternatives to National Objectives

The principal environmental and economic effects of side channel impoundments or subimpoundments in Leech Lake are listed below.

Combined beneficial effects

- Increased wild rice, wildlife, and fish production
- Improved land and water use
- Improved side channel water levels

Combined adverse effects

- Conflicts with canoe route and land use plan of U.S. Forest Service
- Potential increase in nutrients from wild rice development
- Adverse effect on eagle nests identified by U.S. Fish and Wildlife Service
- U.S. Fish and Wildlife Service indicates that much of Sugar Point bog is acid sphagnum muskeg which probably would not be productive wetland habitat for wild rice or wildlife when flooded.
- Benefits do not exceed cost

Alternatives Considered Further

Alternative 1, the no action alternative, is the only economically feasible alternative. It would not improve area conditions for fish and wildlife or wild rice.

Cultural Resources

The headwaters lakes region contains numerous significant prehistoric and historic sites. The Corps has conducted surveys to identify these sites in some areas of the headwaters region. But not all sites in the area have been located. Any action taken to implement any proposed solution to this problem may have an impact on cultural resources.

Prior to implementation, additional surveys will need to be conducted within the project area. All sites located within the area that may be affected by the proposed project will need to be tested to determine their significance. All significant sites listed on or eligible for inclusion on the National Register of Historic Places will need to be mitigated in accordance with Advisory Council on Historic Preservation regulations, 36 CFR 800, prior to construction.

Recommendations

The intent of the Leech Lake Marsh development proposal is to increase fish and wildlife and wild rice benefits in the Mississippi River Headwaters area. Alternative 1 (no action) appears to be the best plan from both the national economic development and the environmental standpoint. No further study is recommended for this proposal.

AITKIN AREA FLOOD CONTROL - PROBLEM 10

The Aitkin area (including urban and rural Aitkin) is located in a reach of the Mississippi River that was once a glacial lake bed. Urban Aitkin (1970 population, 1,553) and rural Aitkin (about 45 farm units, 35 trailers and other homes, and 16,000 agricultural acres) are affected by the operation of Winnibigoshish, Leech, Pokegama, and Sandy Lake dams.

Aitkin has an emergency dike constructed by the St. Paul District in 1969 and 1975. The emergency dike could possibly protect Aitkin against the 1-percent chance flood with portable pumps and sandbagging or filling of low areas. However, east-west city traffic would be disrupted, and utilities and waste disposal facilities would not function properly. The St. Paul District considers Aitkin to be vulnerable and inadequately protected from the 100-year and even smaller floods. The Aitkin area is also protected by a channel diversion constructed by the Corps in 1957. This diversion prevents major flooding in the Aitkin area up to about the 5.9 percent (17-year) agricultural flood level or 12.5-percent (8-year) annual flood event.

The following analysis of structural and nonstructural alternatives is divided into three parts: (1) urban Aitkin, (2) rural Aitkin, and (3) urban and rural Aitkin combined.

Urban Alternative 1: Base Condition (No Action)

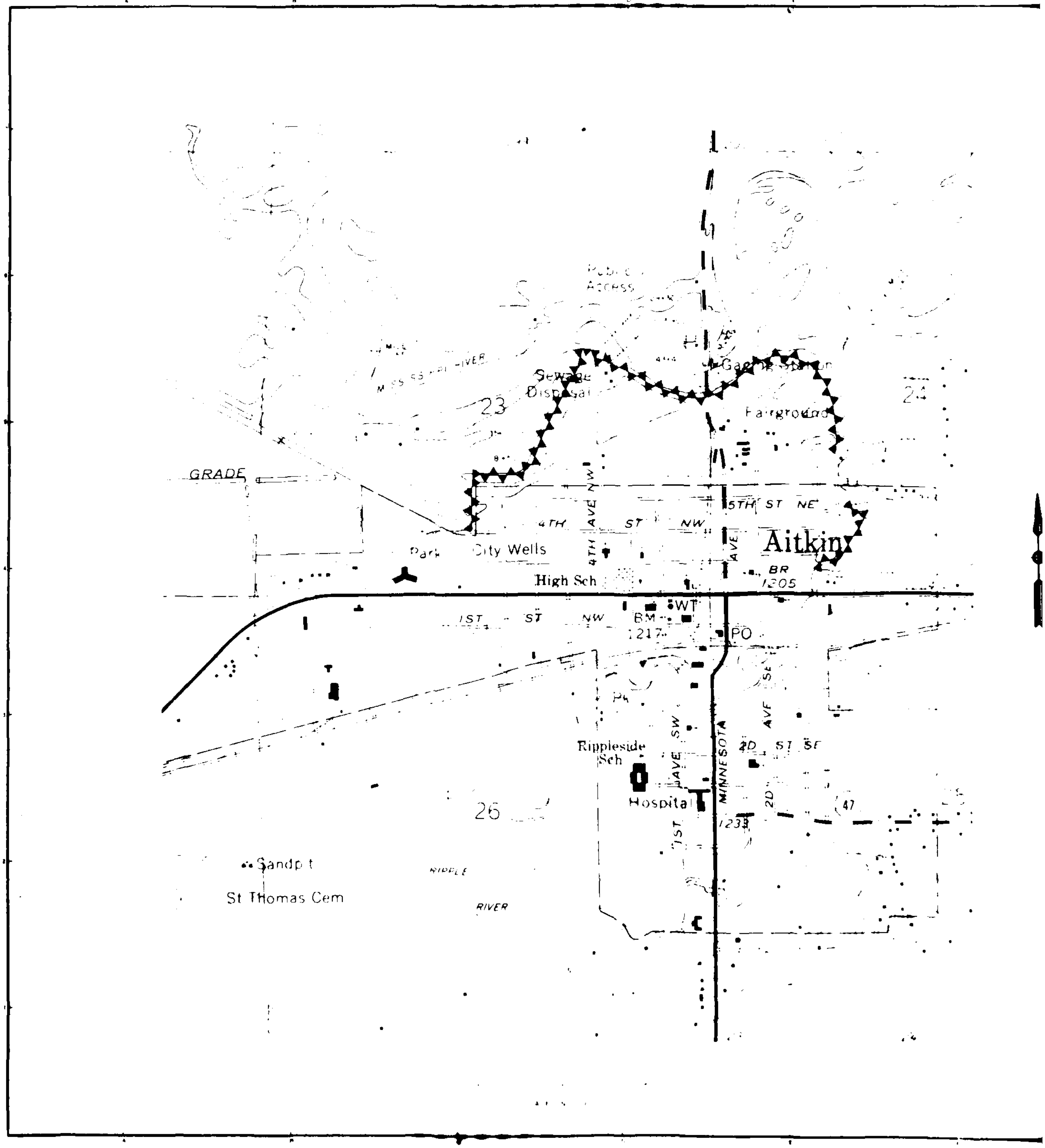
The base condition consists of floodplain regulation and flood insurance required by Federal policies and encouraged by the State of Minnesota. The 1973 Flood Disaster Protection Act established a program of Federal assistance for flood insurance to be related to a unified national program for floodplain management. The 1973 act expanded and improved on an earlier 1968 flood insurance program.

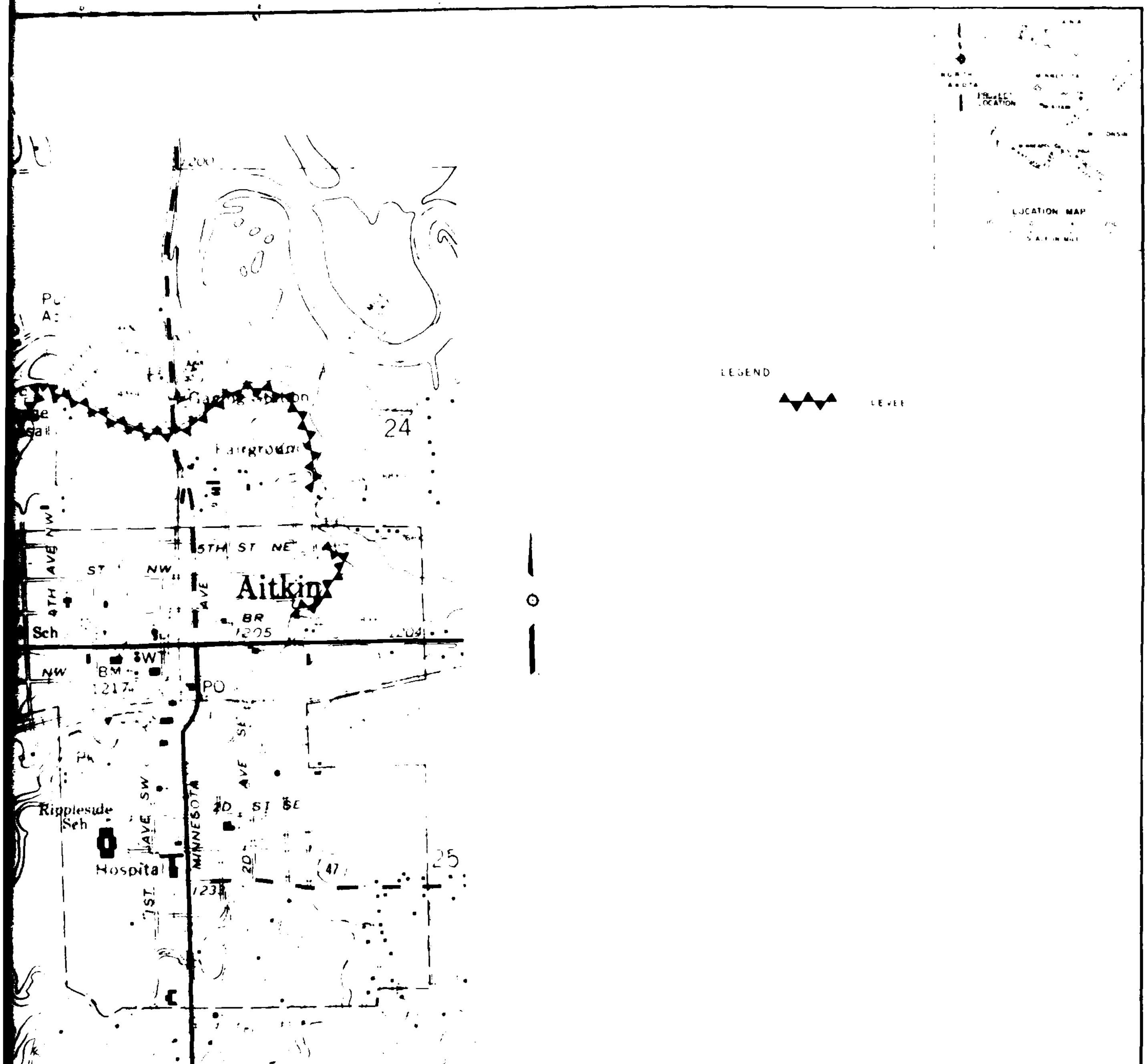
A floodplain information report was prepared for the city in 1975 by the St. Paul District. The 100-year and standard project flood outlines and flood profiles were developed for a 14.8-mile reach of the Mississippi River and a 5.7-mile reach of the Ripple River which flows through Aitkin from the south and enters the Mississippi River just upstream of downtown Aitkin.

Currently, Aitkin is eligible for flood insurance with subsidized premium rates under the 1973 flood insurance program. Flood insurance with subsidized premium rates is available in amounts up to $47,000 for a single-family dwelling and up to $134,000 for multifamily and nonresidential structures. Insurance on contents is available up to a maximum of $13,000 per unit for residences and $134,000 for non-residential units.

Aitkin will participate in the regular flood insurance program using actuarial rates when additional floodplain surveys are completed and regulations are developed. The required floodplain surveys will define the 10-, 50-, 100-, and 500-year floodplains and flood profiles for Aitkin. A flood insurance rate map and building regulations will be developed based on the new surveys. The resulting actuarial insurance rates for urban and rural Aitkin are not expected to be established until 1979. Actuarial rates will permit a more equitable distribution of insurance costs to those participating in the flood insurance program. Coverage up to double the emergency program amounts will be available under the regular program with a flood insurance rate map.

Flood insurance does not prevent flood damages but assists in reimbursing affected property owners for losses sustained from flood damages. It is most effective when used in conjunction with floodplain regulations and other measures. If an insurance program is properly administered, all premiums except that portion used for administrative expenses are returned to property owners through payments for damages. Flood insurance is not considered a complete or effective means of reducing or controlling flood damages in urban Aitkin. However, flood insurance used as a supplement to floodplain regulations could provide limited economic protection for existing urban Aitkin floodplain area development and appears to be the only economically feasible solution at the present time. Existing conditions in urban Aitkin are shown on the following figure.


Public Access
MISSISSIPPI RIVER
Sewage Disposal
23
24
Fairgrounds
GRADE
5TH ST NE
4TH ST NW
4TH AVE NW
Aitkin
Park
City Wells
High Sch
BR 1205
WT
1ST ST NW
BM 1217
PO
Rippleside Sch
1ST AVE SW
MINNESOTA
2D ST SE
2D AVE SE
47
Hospital
1233
26
Sandpit
St Thomas Cem
RIPPLE RIVER



MISSISSIPPI RIVER HEADWATERS STUDY
AITKIN MINNESOTA

EMERGENCY LEVEE LOCATION

ST PAUL DISTRICT CORPS OF ENGINEERS

Urban Alternative 2: Flood Warning and Forecasting Services and Emergency Protection (Base Condition)

Flood warning and forecasting services for urban Aitkin are currently provided by the National Weather Service forecast office in Minneapolis. Warnings of flood stages and crest forecasts can be provided as much as 3 days in advance in the case of rainfall runoff and up to 1 month in advance for snowmelt runoff.

An earth levee presently provides emergency flood protection for urban Aitkin. In conjunction with the existing permanent diversion channel project, this emergency levee is adequate for smaller, less damaging floods but is not considered adequate for larger floods, such as the 100-year flood or the flood that occurred in 1950. (The 1950 flood produced stages about 1 foot higher in Aitkin than the 100-year flood.) Sufficient crest forecast and flood warning time is generally available for snowmelt floods but may not be available for rainfall floods to insure the effectiveness of the emergency levee. Low spots and gaps in the emergency levee would have to be filled, culvert drains plugged, portable pumps installed, and normal waste treatment discontinued in the event of a 100-year flood. These measures would continually disrupt biological systems and the scenic quality of urban Aitkin flood prone areas. These measures can also cause much personal inconvenience and disruption to floodplain residents.

Flood warning and forecasting services and emergency protection are not considered socially, economically, or environmentally acceptable as a total solution to the urban Aitkin flood problem. However, flood warning and forecasting services should continue to provide a valuable service to urban Aitkin. The present emergency levee should be maintained to provide protection for lesser floods until a more permanent solution is established.

Urban Alternative 3: Flooded Area Evacuation

Permanent evacuation of the urban Aitkin floodplain area would involve purchase of lands, removal and relocation of improvements, evacuation and resettlement of residents, and permanent conversion of evacuated lands to uses less susceptible to flood damage. Lands acquired in this manner would be used for parks, "natural" areas, or other purposes which would not be damaged so severely by floods.

Evacuation would remove approximately 200 homes and 44 commercial units from the urban area floodplain. The evacuated homes and businesses would be moved to other sites, probably on the southeast side of Aitkin, thereby establishing, in effect, a new business community and expanding urban development to the south. Relocation to this site would remove about 110 acres of cropland or open areas from their present uses. This alternative has a total first cost of $22,898,000 and an unfavorable benefit-cost ratio of 0.03.

Urban Alternative 4: Flood Proofing

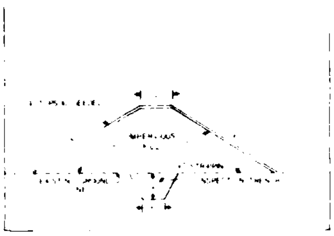
Alternative 4 involves flood proofing buildings subject to flooding. Flood proofing is a combination of structural changes and adjustments to buildings to reduce or eliminate flood damages. In most instances, flood proofing involves elevating buildings above the 100-year flood level or sealing off building openings to prevent water from entering window wells or floor drains.

Alternative 4 would require raising 200 homes and 44 businesses and utilities above elevation 1207. The alternative has a first cost of $1,956,000 and an unfavorable benefit-cost ratio of 0.21.

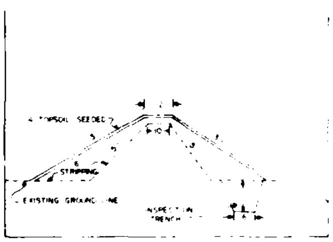
Urban Alternative 5: Permanent Levee

Alternative 5 involves constructing a permanent levee at the location of the present emergency levee and extending the permanent levee to protect the principal Aitkin flood area for the 100-year flood level. The existing emergency levee would be used as a base. The 13,600-foot permanent levee would be constructed with 3 feet of freeboard over the 100-year flood level.

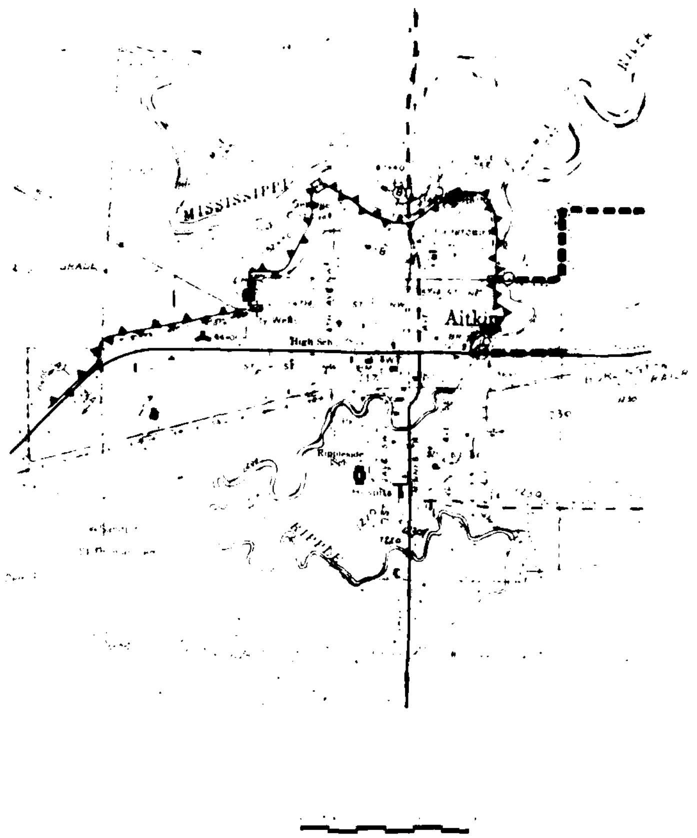
The first cost of the proposed permanent levee is $5,242,000; the unfavorable benefit-cost ratio is 0.10. The proposed plan is shown on the following figure.

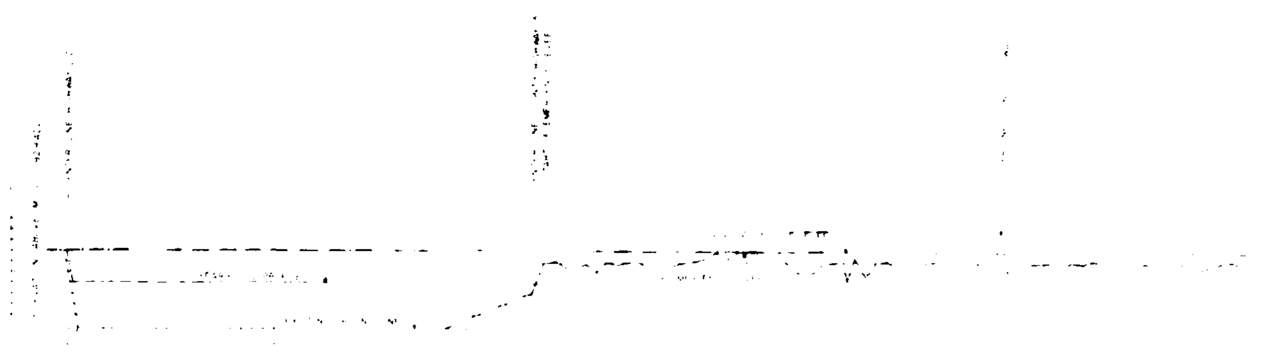


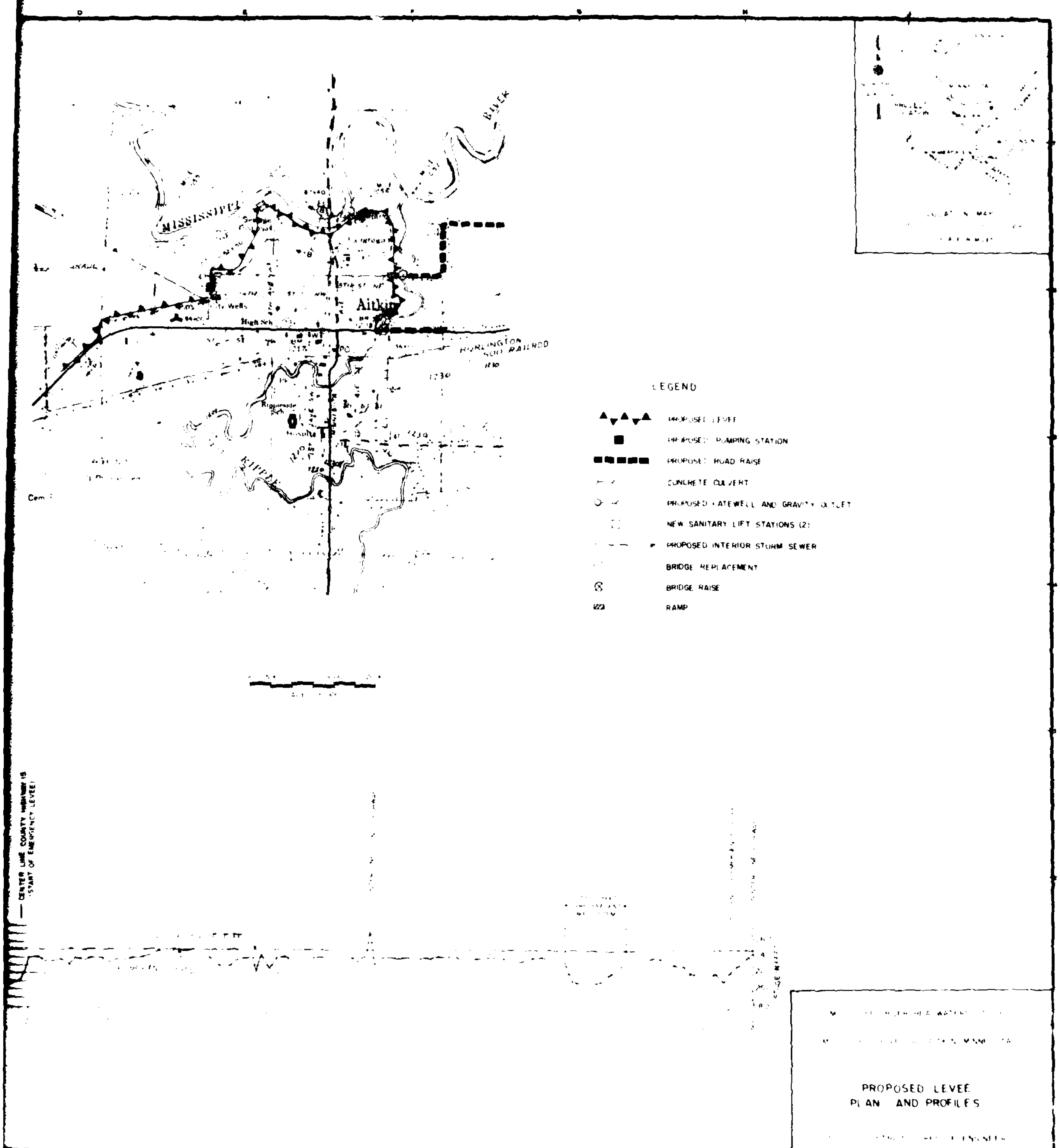
SECTION A-A
TYPICAL LEVEE SECTION
NO SCALE



SECTION B-B
TYPICAL LEVEE SECTION
NO SCALE






MISSISSIPPI
RIVER
Aitkin
BURLINGTON
SOO RAILROAD
LEGEND
PROPOSED LEVEE
PROPOSED PUMPING STATION
PROPOSED ROAD RAISE
CONCRETE CULVERT
PROPOSED GATEWELL AND GRAVITY OUTLET
NEW SANITARY LIFT STATIONS (2)
PROPOSED INTERIOR STORM SEWER
BRIDGE REPLACEMENT
BRIDGE RAISE
RAMP
CENTER LINE COUNTY HIGHWAY 15
(START OF EMERGENCY LEVEE)
PROPOSED LEVEE
PLAN AND PROFILES

Rural Alternative 1: Base Condition (No Action)

The base condition of floodplain regulation and flood insurance applies to rural Aitkin as it does to urban Aitkin with one major difference: the Federal flood insurance program does not protect against loss of livestock or crops. Crop or livestock losses are generally covered under regular insurance policies issued by private insurance carriers. Federal flood insurance policies apply only to walled and roofed buildings and their contents.

Rural Aitkin residents are eligible for flood insurance with subsidized premium rates under the 1973 flood insurance program. Flood insurance with subsidized premium rates is available in amounts up to $46,000 for a single family dwelling and up to a maximum of $13,000 per unit on contents.

Actuarial insurance rates will be established for rural Aitkin based on studies currently under way. These studies will define the 10-, 50-, 100-, and 500-year floodplains and flood profiles for urban Aitkin. Coverage up to double the emergency program amounts will be available under the regular program when the actuarial rates are established (some time after 1979).

Flood insurance is not considered a complete or effective means of reducing or controlling flood damages in rural Aitkin. Flood insurance used as a supplement to floodplain regulations could provide limited economic protection to existing rural area buildings subject to flooding.

Rural Alternative 2: Flood Warning and Forecasting Services and Emergency Protection

This alternative is also a base condition (no action) alternative for rural Aitkin. Flood warning and forecasting services for rural Aitkin are currently provided by the National Weather Service forecast office in Minneapolis. Warnings of flood stages and crest forecasts at the Aitkin gage can be provided from 3 days to 1 month in advance for rainfall runoff and snowmelt runoff, respectively.

Emergency flood protection in the form of individual home or farmstead diking could possibly be built in advance of a snowmelt flood if the longer period of warning time were available. This action would not prevent crop loss but would protect livestock and buildings. However, it is against Corps policy to provide emergency flood protection for private property on an individual basis or where public facilities are not involved. Some of the overall economic loss to rural property and livestock could be avoided with advance flood warnings. Home contents and animals could be moved to more secure areas in advance of a flood. However, all of the above emergency measures would cause much personal inconvenience and continual disruption to floodplain residents.

Rural Alternative 3: Flooded Area Evacuation

Evacuation of the rural floodplain would consist of purchase of lands, removal and relocation of buildings and improvements, evacuation and resettlement of residents, and permanent conversion of evacuated lands to uses less susceptible to flood damage. Lands acquired in this manner would be used for parks, "natural" areas, or other purposes which would not be damaged so severely by floods. Evacuation would remove approximately 45 farm units and 35 trailers and homes from the floodplain. The total first cost of this alternative is $32,696,000; the unfavorable benefit-cost ratio is 0.09.

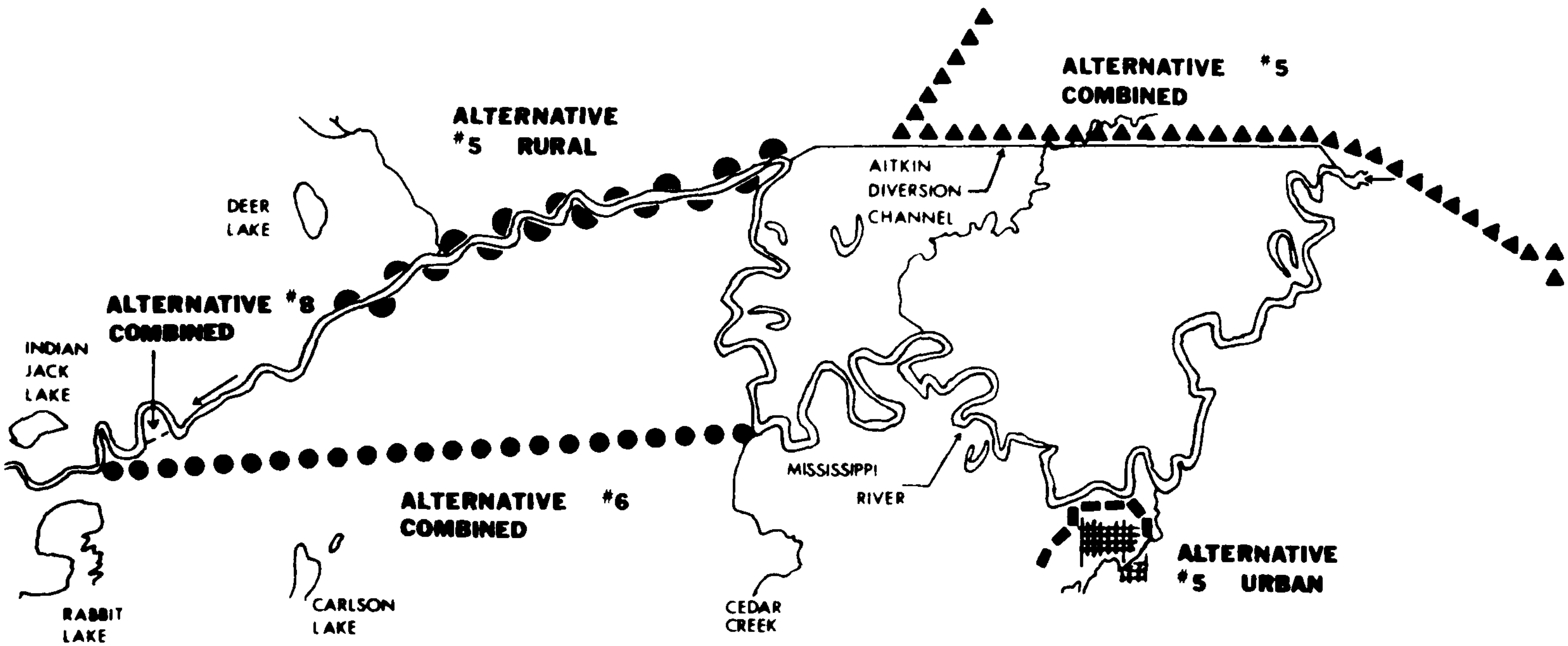
Rural Alternative 4: Flood Proofing

Alternative 4 involves flood proofing Aitkin area farmsteads and other rural buildings in the floodplain. The most feasible flood proofing method would involve constructing earth dikes around farmsteads and other buildings with access ramps in and out of the inclosure. At least one individual in the rural Aitkin area has constructed such a dike around his farm buildings since the 1975 flood. However, this ring dike has not yet been tested by floodwaters.

The first cost for flood proofing 45 farmsteads, 27 trailers, and 8 homes is $1,490,000. This alternative has an unfavorable benefit-cost ratio of 0.25.

Rural Alternative 5: Removal of Pine Knoll Ledge

This alternative, proposed by rural residents, involves excavation of the alluvial channel bottom of the existing Mississippi River channel downstream from the Pine Knoll area. There is evidence of a rock or gravel bar at one location in the channel, but there is no rock ledge in the affected channel reach. Excavation of 3 to 5 feet of channel depth in the 10-mile reach starting about 16 miles downstream of the Aitkin gage would have a first cost of $6,901,000. The channel cut could not possibly eliminate all rural and urban damages in the Aitkin area. However, assuming that it could, the project would still not be feasible at a benefit-cost ratio of 0.41. This alternative is shown along with other alternatives on the following figure.



ALTERNATIVE 7 COMBINED IS AN ENLARGED AITKIN DIVERSION WITH PINEKNOLL LEDGE REMOVED ALTERNATIVE 5 RURAL

5000 0 5000 10000
SCALE IN FEET

MISSISSIPPI RIVER HEADWATERS STUDY

AITKIN ALTERNATIVES

ST PAUL DISTRICT CORPS OF ENGINEERS

Rural Alternative 6: Evacuation of Flooded Farmsteads

This alternative differs from alternative 3 in that the farmlands would not be purchased and would be retained by the original owners. Only the rural residents, buildings, and improvements would be evacuated from the floodplain. Evacuation would remove 45 farm units and 35 trailers and homes from the floodplain. The total first cost of this alternative is $5,302,000, and the proposal would have a benefit-cost ratio of 0.11.

Rural Alternative 7: Rural River Channel Diking

This alternative would consist of constructing earth levees along both sides of the natural Mississippi River channel from the inlet to the outlet of the present Aitkin diversion channel (mile 1064 to mile 1041). The levees would have a top elevation of 1202, generally follow the 1,200-foot contour wherever possible along the river, and connect to the existing urban emergency earth levees. This alternative would include approximately 44 miles of low diking with closures on 16 minor drainage courses or tributaries and 12 major pumping structures.

Alternative 7 is not feasible with a first cost of $17,688,000 and a benefit-cost ratio of 0.16.

Combined Alternatives 1 Through 4

Several alternatives were considered that could prevent both rural and urban Aitkin area flooding. Alternatives 1 through 4 discussed previously for both the urban and rural Aitkin area could be combined, and are summarized in a table at the end of this section.

Combined Alternative 5: Upstream Dam Above Aitkin

This alternative would consist of constructing a flood control dam on the Mississippi River upstream of Aitkin, just downstream of the Rice River. No really good locations exist for a dam upstream of

Aitkin because of the flat terrain. However, if a dam were constructed to store 340,000 acre-feet of floodwater, it would flood about 75 to 80 square miles of marsh and low-lying area (340,000 acre-feet is the amount by which the 1950 flow exceeded the present 12,000-cfs Mississippi River and channel diversion capacity through and around Aitkin).

The dam would benefit about 16,000 acres (25 square miles) but would flood 75 to 80 square miles. The first cost of such a dam would be $36 million; the unfavorable benefit-cost ratio would be 0.10.

Combined Alternative 6: Diversion (Cedar Brook to Towhead Rapids)

This alternative would consist of a 37,000-foot channel that would divert Mississippi River flows at Cedar Brook (mile 1045) to Towhead Rapids (mile 1030.3). The diversion channel would carry half of the 100-year design flow of 19,700 cfs at Aitkin.

The channel would alleviate flooding in urban areas downstream of Aitkin but would only partially alleviate the 100-year flood damages in Aitkin and upstream rural areas. The first cost of this alternative is $46,955,000. If it could eliminate all of the area flood damage, the channel would still have an unfavorable benefit-cost ratio of 0.07.

Combined Alternative 7: Enlarge Aitkin Diversion and Remove Pine Knoll Ledge

This alternative would consist of enlarging the existing Aitkin diversion channel to pass 14,700 cfs, with the main channel through Aitkin passing the remainder of the 100-year flow (5,000 cfs). This feature would be combined with alternative 5 for urban Aitkin, removing the ledge rock at Pine Knoll.

This alternative is not feasible with a first cost of $87,187,000 and a benefit-cost ratio of 0.04.

Combined Alternative 8: Towhead Rapids Channel Cutoff

This alternative would consist of constructing a channel cutoff upstream of Towhead Rapids at approximately mile 1031.5-1032.5 on the Mississippi River. This cutoff could possibly be expected to reduce flood levels in the Pine Knoll (mile 1040.1) and Aitkin (mile 1056.0) areas by one-half foot maximum.

This alternative is not feasible with a first cost of $1,828,000 and a benefit-cost ratio of 0.32.

Combined Alternative 9: Modification of Brainerd Dam

This alternative would consist of enlarging the discharge capacity of Brainerd Power Dam at mile 1003.7 on the Mississippi River. The purpose of the modification would be to lower the 100-year flood elevation at Pine Knoll (mile 1040.1) and at Aitkin (mile 1056.0). However, calculations using the HEC-2 backwater program show that the Brainerd Dam has no effect on the high water stages at Pine Knoll or Aitkin. The effects of backwater caused by the Brainerd Dam extend only 23 miles upstream from the dam, or to mile 1026.7. Therefore, no flood control benefits are possible with modification of the dam, and no cost estimate was determined for this work.

Review of Alternatives

Cost data for the structural and nonstructural alternatives are summarized in the following table.

Summary of Aitkin, Minnesota, flood control alternatives

Alternative	First cost	Annual cost[1]	Maximum annual benefit[3]	Benefit-cost ratio
Urban Aitkin				
1. Flood insurance	-	$282,000	282,000	1.0
2. Flood warning and forecasting[5]	-	-	-	-
3. Evacuation	$22,898,000	1,747,000	45,600	0.03
4. Flood proofing	1,956,000	149,300	32,100[2]	0.21
5. Permanent dike	5,242,000	446,600	45,700	0.10
Rural Aitkin				
1. Flood insurance	-	57,400	57,400	1.0
2. Flood warning and forecasting[5]	-	-	-	-
3. Evacuation	32,696,000	2,495,000	225,000	0.09
4. Flood proofing	1,490,000	188,700	46,500	0.25
5. Removal of Pine Knoll ledge	6,901,000	548,300[6]	225,000	0.41
6. Evacuation with no land purchase	5,302,000	404,500	46,500	0.11
7. Rural river channel diking	17,679,000	1,402,000	Less than 225,000	0.16
Aitkin and rural Aitkin[4]				
1. Flood insurance	-	339,300	339,300	1.0
2. Flood warning and forecasting[5]	-	-	-	-
3. Evacuation	55,594,000	4,242,000	270,800	0.06
4. Flood proofing	3,446,000	337,000	78,700	0.23
5. Upstream dam above Aitkin	36,180,000	2,796,000	270,800	0.10
6. Diversion (Cedar Brook to Towhead Rapids)	46,955,000	3,707,000[6]	270,800	0.07
7. Enlarge Aitkin diversion and Pine Knoll excavation	87,187,000	6,958,000[6]	270,800	0.04
8. Towhead Rapids channel cutoff	1,828,000	145,500[6]	47,800	0.32
9. Modify Brainerd Dam	- Would not be effective - no cost estimate determined			

(1) Includes operation and maintenance costs (7 5/8-percent interest and 100-year project life.

(2) 100-percent flood proofing in Aitkin is not possible because of permeable soils - use 70 percent x $45,700 = $32,100 annual benefits.

(3) Flood insurance benefits assumed equal to flood insurance costs.

(4) Benefits and costs for rural and urban Aitkin are the sum of individual costs and benefits.

(5) Costs and benefits for emergency evacuation or protection measures would vary, depending on magnitude of flood predicted.

(6) 7 5/8-percent interest, 50-year project life.

Alternatives Considered Further

None of the structural and nonstructural alternatives is feasible for the Aitkin area except the flood insurance-floodplain regulation alternative (alternative 1) combined with flood forecasting and warning (alternative 2).

One possibility not considered in evaluation of the previous alternatives is the attempt to justify a structural plan for the Aitkin area on the basis of benefits that could be expected to result from changes in headwaters lake operations made possible by one of the combined Aitkin area structural plans (alternatives 4 through 7) or for rural alternative 5 (removal of Pine Knoll ledge). These plans could benefit the four upstream lakes (Winnibigoshish, Leech, Pokegama, and Sandy) if the lakes did not have to restrict flood outflow releases because the Aitkin area was already protected by adequate flood control measures.

However, not all of the damage in the four upstream headwaters lakes could be prevented simply by constructing improvements in the Aitkin area and, thereby, eliminating that area as a lake operation concern. Even if half of the average annual damages on the four upstream lakes were eliminated, the maximum lake benefits would still be insufficient to justify the cost of a structural plan for the Aitkin area. The following table shows the economic data for the five alternatives previously mentioned.

Flood control cost data for rural and urban Aitkin

Alternative	First cost	Annual cost	Maximum annual benefit (2)	Benefit-cost ratio
4. Flood proofing	$3,446,000	$326,100 (1)	$274,300	0.84
5. Upstream dam above Aitkin	36,180,000	2,796,000 (1)	466,500	0.17
5. Removal of Pine Knoll ledge (rural Aitkin only)	6,901,000	548,300 (3)	429,800	0.77
6. Diversion (Cedar Brook to Towhead Rapids)	46,955,000	3,707,000 (3)	466,500	0.12
7. Enlarge Aitkin diversion and Pine Knoll excavation	87,187,000	6,958,000 (3)	466,500	0.07

(1) Includes operation and maintenance costs, 7 5/8-percent interest, 100-year project life.
(2) One-half the maximum possible headwaters lakes average annual damages for Winnibigoshish, Leech, Pokegama, and Sandy Lakes total $196,000, added to Aitkin area benefits previously tabulated.
(3) 7 5/8-percent interest, 50-year project life.

Other factors would make even those alternatives closest to feasibility in the above tabular values less feasible. For example, simply flood proofing urban and rural properties would not prevent agricultural flooding which would, in turn, preclude implementation of this alternative. Also, removal of Pine Knoll ledge would not prevent 100 percent of the flood damage in the Aitkin area. Preliminary calculations show that the benefits from removal of Pine Knoll ledge could not be obtained without first enlarging the Aitkin diversion or excavating upstream from Pine Knoll toward Aitkin.

A second possibility not referred to in the previous evaluation of alternatives for Aitkin is a possible change in lake operating plans upstream of Aitkin. This alternative was evaluated to some extent under the problem 1 section dealing with headwaters lakes operating plans.

It appears that a modification of lake operating plans for flood control could aid Aitkin to a small degree but at a much larger cost in economic damages to headwaters lakes area properties. A somewhat different modification of lake operation for low-flow releases to supplement Twin Cities water supplies in critical years would still aid Aitkin an even smaller amount, but would be highly beneficial to the Twin Cities metropolitan area. This is referred to in the problem 1 section as a "low-flow plan of operation." The low-flow plan benefits to Twin Cities area interests for water supply would greatly exceed those added flood losses to headwaters lakes interests under this type of operation. In any event, no large beneficial effect from a changed operation plan appears possible for the Aitkin area.

Cultural Resources

The headwaters lakes region contains numerous significant prehistoric and historic sites. The Corps has conducted surveys to identify these sites in some areas of the headwaters region. But not all sites in the area have been located. Any action taken to implement any proposed solution to this problem may have an impact on cultural resources, except those actions such as alternative 2 which include only flood warning and forecasting services.

Prior to implementation, additional surveys will need to be conducted within the project area. All sites located within the area that may be affected by the proposed project will need to be tested to determine their significance. All significant sites listed on or eligible for inclusion on the National Register of Historic Places will need to be mitigated in accordance with Advisory Council on Historic Preservation regulations, 36 CFR 800, prior to construction.

Recommendations

The only economically feasible solution to flood problems in the Aitkin area is alternative 1, the flood insurance-floodplain regulation alternative, combined with alternative 2, flood forecasting and warning.

No further studies are recommended concerning flood control at Aitkin.

STAGE 3 CONCLUSIONS

The 10 water resource problem areas previously identified and evaluated in this report should be dealt with as described in the following paragraphs.

Optimum Lake Operating Plans

The stage 2 study analysis concentrated on four possible operating plans: (4) natural conditions, (1) present conditions (3) Aitkin flood protection, and (2) Twin Cities low-flow supplement. The Stage 2 study concluded that a low-flow supplement plan showed promise and was economically feasible. Further analysis was made of these same four plans and additional operating plan variations during a subsequent Stage 3 study analysis. The Stage 3 analysis showed that a minimum flow of 1,600 cfs (plan 2, or year 2015 estimated minimum metropolitan area water supply needs) could be maintained at Anoka without exceeding the original minimum operating limits for Winnibigoshish, Leech, and Pokegama Lakes. However, the three lakes would be drawn below their present lower operating limits during several periods in the 1930's to maintain the Anoka 1,600-cfs flow.

The 1,600-cfs flow is approximately the largest flow that could be maintained at Anoka. A somewhat higher flow of 2,275 cfs, for example (plan 5), would result in shortages at Anoka in 37 out of 564 months of record, or about 7 percent of the 47-year period of record. (The shortages would occur during 10 years of the 47-year period.)

The District recommends that neither plan 2 nor 5 be adopted; however, plan 2 might be used on an emergency basis. The District also recommends that the cities of St. Paul and Minneapolis develop alternate water supply sources and conservation techniques that will not only provide an added margin of safety during drought conditions but would protect the cities in the event of an unexpected water quality problem, such as from a chemical spill or other unforeseen incident.

Based on the Stage 3 studies, it is recommended that the present plan of operation (plan 1) be retained as the accepted operating plan for the six headwaters lakes. In addition, it is recommended that the conservation operating plan (plan 9) features for Winnibigoshish and Leech Lakes (modified for Leech) be *incorporated in the present plan*. These features are not in reality different from the present plan of operation, but are merely a refinement of the objectives of that plan and are within the present plan's operating limits.

Bank Erosion Control on Six Headwaters Lakes

No structural improvements or changes in lake operation are recommended to protect large expanses of shoreline, although protection of individual properties may be justified. The current plan of operation for each of the six headwaters lakes has stabilized or caused a decline in erosion on the lakes. Recent detailed studies of erosion on Lake Winnibigoshish present a good example of the erosion decline as summarized in the following conclusions for the period 1939 to 1969.

a. Fifty-six percent of the total erosion could have occurred during only 3 years (1943, 1944, and 1950).

b. Approximately two-thirds of the total erosion occurred in the first 12 years of the period 1939-1969.

c. There was an overall decline in potential erosion.

No further studies are recommended for this problem. Erosion at archeological sites will be adressed further under existing authorities.

Erosion Problems Downstream of Pokegama Dam

No economically feasible solution was identified for the problem area located about 10 miles downstream of Pokegama Dam near Blackberry. No structural measures are recommended for this area which, over the past 20 years, has experienced several channel changes determined to be part of natural river processes. No additional study will be made of this problem.

White Oak Lake Water Levels

No further action is recommended for stabilizing the White Oak Lake water levels. A proposed dam at Days High Landing is economically feasible and would help stabilize White Oak Lake levels, but the Minnesota Department of Natural Resources is opposed to this development. No additional study of this problem will be made.

Black Bear and Miller Lakes Flood Problem

A dam or closure structure to prevent backup flooding from the Mississippi River would give the best flood protection for this area and is economically feasible. Crow Wing County has recently agreed to act as an authorized local sponsor for this project. It is recommended that the levee (closure structure) be evaluated in more detail under the small projects authority and a detailed project report for construction be prepared for the approval of the Chief of Engineers.

Headwaters Lakes Perimeter Dikes

The 28 perimeter dikes located around Winnibigoshish, Pokegama, Sandy, and Pine River Lakes should be maintained to preserve the desired headwaters lakes operation schedules. These dikes are in varying states of repair, from satisfactory to having serious seepage and possible overtopping and stability problems. Initial inspections were limited by study funds, but these dikes should be scheduled for detailed inspection, testing, and upgrading, and should be included in the District's regularly scheduled maintenance program under present funding authority. However, any proposed dike raise would require additional authority to implement.

The dikes should be included for further evaluation under the Dam Safety Assurance Program, a new Corps program in response to a 23 April 1977 Executive Order. No further investigation of the 28 perimeter dikes is recommended for the Mississippi River Headwaters Study.

Whitefish Lake Channel Obstructions and Marking

Permanent connecting channels at six locations in the Whitefish Chain of Lakes are economically feasible. These six connecting channels could be dredged to provide adequate width and depth at low water elevations. The channels would be paralleled, as required, by rock jetties to insure permanence and provide shore access for fishing. This alternative is not recommended for further investigation because no authorized sponsor is available. More detailed study could be conducted under the small projects authority and a detailed report for construction could be prepared for the approval of the Chief of Engineers, if a project sponsor is found.

Leech Lake Dam Inlet Channel Restrictions

The present Leech Lake inlet channel could be dredged to improve the hydraulic capacity of the Leech Lake Dam. The flow capacity of the dam has been reduced since 1884 when the dam was originally constructed. Shoaling in the vicinity of the Leech Lake entrance is the primary obstruction, and removal of about 186,000 cubic yards of material is necessary. This alternative will not be studied further under the current Mississippi River Headwaters study authority. The inlet channel can be evaluated further and dredged under existing authorities. However, design funding for this work is not currently scheduled.

Leech Lake Marsh Channel Cutoffs

The development of marsh areas in the 4-mile reach below Leech Lake Dam is not economically feasible. Four subimpoundments in Leech Lake to improve fish and wildlife habitat and to offset earlier channel dredging environmental losses are similarly not economically feasible. No further studies are recommended for these marsh development proposals.

Aitkin Area Flood Problems

No economically feasible permanent flood protection plan exists for Aitkin or for downstream rural Aitkin. It is recommended that local residents in the affected area consider purchasing flood insurance and that floodplain zoning and regulations be developed and enforced to control further floodplain development.

Flood insurance, the existing Aitkin diversion channel, flood forecasting and warning, and the existing Aitkin emergency dike will provide some protection and economic compensation for the area.

The feasibility of developing a modified flood control operating plan for Aitkin in conjunction with a review of a number of operating plan variations was evaluated in stage 3 studies. The stage 3 studies expanded on the earlier stage 2 economic and hydrologic analysis of the relationship between Mississippi River Headwaters Lakes operating plans and Pokegama-Sandy-Aitkin flood control. On the basis of the stage 2 and stage 3 analyses, no modification of the present rule-curve operation plan between Pokegama Lake, Sandy Lake, and the Aitkin area is recommended. No further analysis of this interrelationship is planned under the current study, nor is there an economically feasible structural solution to the Aitkin area flood problem.

PUBLIC INVOLVEMENT

Contacts and input from the public were obtained in several ways during the study (see appendix E for details). Initial results or solutions to the 10 problem categories were reviewed with the principal study contact group (Mississippi River Headwaters Association) in June 1977, in June 1978, and in September 1979. The same results were provided to the State-Federal Steering Committee and to pertinent Twin Cities officials for their review and comment.

A number of mailings were made to the above two representative groups, and meetings were held with individual groups such as the Whitefish Lake and Pokegama Lake Property Owners Associations, the Black Bear and Miller Lakes interests, and the Leech Lake Reservation Business Committee. Several informal meetings were held with Aitkin representatives, and alternative summary data were provided for the city's review. Other interests were advised of study progress through individual mailings, meetings, or telephone conversations. Progress reports were mailed to over 800 people on the study mailing list in March, July, and October 1977; February and August 1978; March 1979; and February 1980. Copies of these progress reports are included in the report appendix.

A stage 2 summary report, a contractor's report, and report appendixes were distributed for review and comment to Federal, State, regional, and local agencies interested in the study during November and December 1979. The Mississippi River Headwaters Association and State-Federal Steering Committee members and local libraries all received copies of these reports for review and comment. Copies of the current stage 3 report will be provided to the same interest groups.

RECOMMENDATIONS

I recommend that the United States take the following action with regard to the 10 water resource problems evaluated by this study:

(1) Optimum operating plans - No action. The six headwaters lakes should be operated in accordance with the current plan of operation and should incorporate those conservation features previously identified for Winnibigoshish and Leech Lakes whenever possible. This plan allows the District Engineer some latitude in responding to the needs of all interests affected by the lake operation. The needs of navigation, flood control, recreation, fish and wildlife, hydropower, and wild rice production are all currently recognized in fact under the present operating plan.

The current operating plan allows the District Engineer some latitude in responding to the public needs on an annual basis by making adjustments to the operating plan. Adjustments are made on a case-by-case basis after consultation with State of Minnesota authorities and concerned interests. Conservation features previously identified and adopted for Winnibigoshish and Leech Lakes are typical of these adjustments. Changes made for any length of time are enacted only after a public hearing and after an environmental assessment is prepared. No recommendations are made to change the Department of the Army regulations which govern the lake operating plan currently in effect.

(2) Bank erosion control on the six headwaters lakes - Continue action on a case-by-case basis under established operation and maintenance or other authorities.

(3) Erosion problems downstream of Pokegama Dam - No action. The identified problems are the result of natural river processes, and no economically feasible solutions were identified.

(4) White Oak water levels - No action. An economically feasible plan of improvement is available, but the plan is adamantly opposed by the State of Minnesota.

(5) Black Bear and Miller Lakes flood problem - A closure structure is being evaluated in more detail under the small projects authority. No further action is recommended under the Mississippi River Headwaters study.

(6) Headwaters lakes perimeter dikes - These dikes are being evaluated further under the Corps' Dam Safety Assurance Program. No further action is recommended under the Mississippi River Headwaters study.

(7) Whitefish Lake channel obstruction and marking - This project lacks local support and no further action is recommended under the Mississippi River Headwaters study.

(8) Leech Lake channel restrictions - No further action is recommended under the Mississippi River Headwaters study. However, channel dredging is being scheduled under the District's authorized operation and maintenance program.

(9) Leech Lake channel cutoffs - No action recommended. This project is not economically feasible.

(10) Aitkin area flood problems - No further action is recommended under the Mississippi River Headwaters study. No economically feasible structural solution exists. Affected area residents should avail themselves of flood insurance and floodplain regulations under other established procedures and authorities.

In summary, I recommend that the Mississippi River Headwaters study be referred to Congress for information.

EDWARD G. RAPP
Colonel, Corps of Engineers
District Engineer

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