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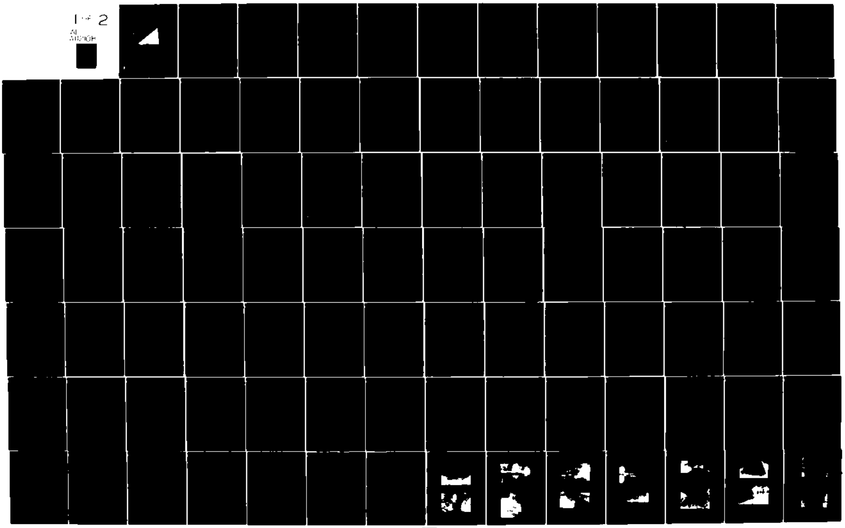

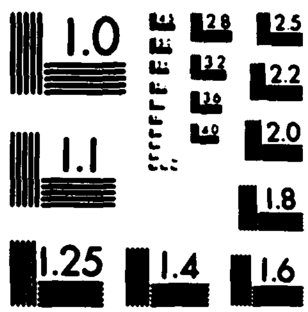

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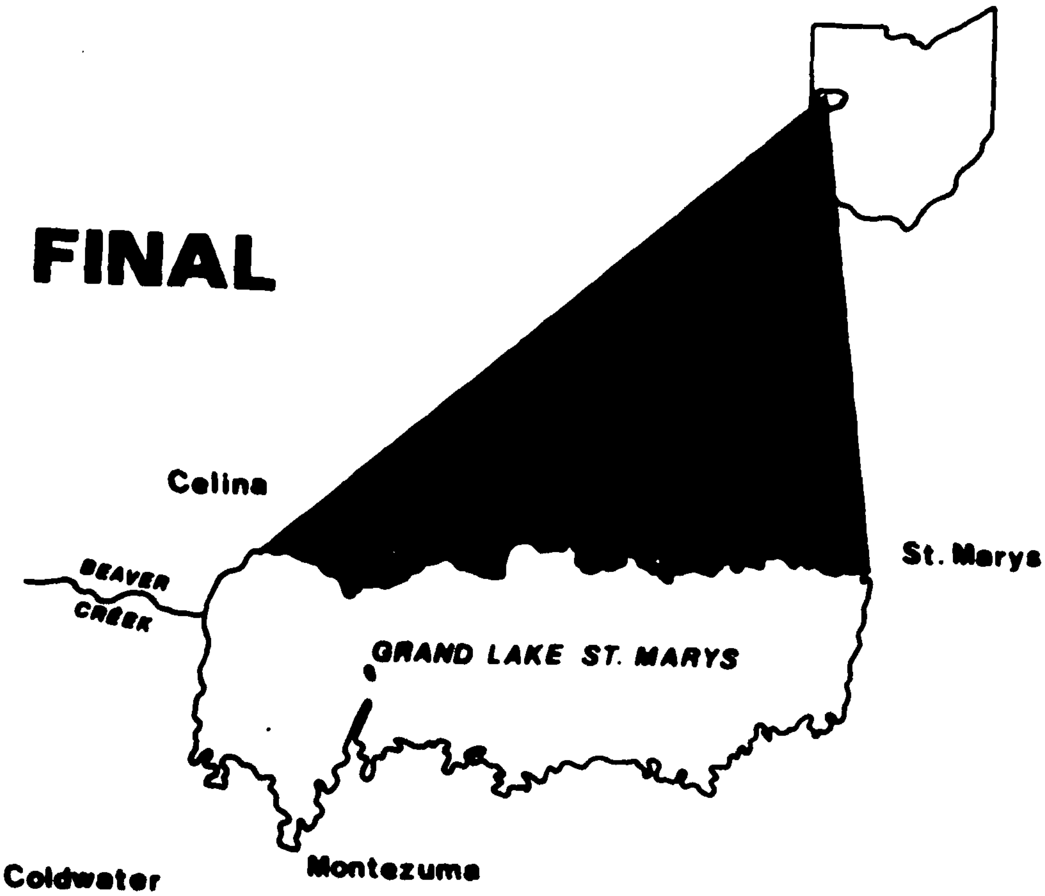

Survey Report for Flood Control and Allied Purposes

Volume 1 of 2 Main Report

CORPS OF ENGINEERS
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.

AUGUST 1981

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Anglaize County, Ohio	Grand Regional Sewer System
Mercer County, Ohio	Water quality
Beaver Creek, Ohio	Water resources development

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

The Grand Lake St. Marys shore flood problem is caused by the inability of the 10.6- mile long westerly outlet channel to discharge sufficient flood flows to keep pace with inflow to the lake during peak periods plus the effect of wind setup and wave runup on low-lying developed areas when lake levels are high.

Beaver Creek flood problems are caused by a combination of a limited flood control capability of Grand Lake St. Marys, poor surface drainage, low stream gradient, constriction to flow, and high stream stages for a long period of time (over)

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) which cause inadequate outlet conditions for numerous artifical agricultural drains.

Lake water quality has been declining in recent years. Four seperate water quality problems have been identified as causing the deterioration. Bacterial contamination from human sources threatens body contact recreation, particularly in areas of greatest development. The rich nutrient content of the lake results in excessive algae and suspended sediment, resulting in unattractive conditions for recreators. Accumulation of sediment, eroded from upland areas, and unprotected shoreline have reduced the lake depth.

A range of structural and nonstructural flood damage reduction measures were examined. Nonstructural measures investigated for Beaver Creek are not viable solutions because of the agricultural character of the flood plain. Structural measures considered for Beaver Creek including detention basins, diversion, clearing and cleaning, channel improvements, and agricultural levees were determined to be economically infeasible.

Nonstructural flood plain management measures generally will not improve the flood problems for existing structures on the south shore, but regulations adopted by local governments either voluntarily or as required by participation in the Flood Insurance program could be used to reduce damages to future development. Structural measures such as groins and shoreline levees (dikes) are not perceived to be economically feasible. Fixed breakwaters can be effective in reducing shoreline flooding and erosion, but economic benefits are derived primarily from the potential for increased visitation and not from flood damages reduced.

Lake water quality problems related to nutrient and algae control appear better resolved through reduction of nutrient loads to the lake and in particular control of agricultural and livestock waste sources rather than by in-lake treatment approaches.

Emphasis should be placed on the control of erosion and critical soil loss areas in the watershed and unprotected shoreline areas. An extensive lake-wide dredging program, besides being cost prohibitive, would result in no significant improvement in water quality or flood control storage. In-lake dredging of selected near-shore zones as is currently being performed should be contained for improving lake access and boater safety, public land development, and to keep pace with the current rate of sediment accumulation and r[illegible] ribution.

Grand Lake St. Marys, Ohio

MAIN REPORT

Volume 1 of 2

Survey Report
for
Flood Control
and
Allied Purposes

Louisville District Corps of Engineers
Department of the Army

August 1981

SYLLABUS

The purpose of this study was to investigate flood and related water resource problems in the vicinity of Grand Lake St. Marys in Ohio to determine the need for and feasibility of improvements to solve these problems.

The principal areas of concern included flood damage, water quality, and recreation problems. Priority flood problem areas are on the south shore of Grand Lake St. Marys and along Beaver Creek, the western outlet channel of the lake. The Grand Lake St. Marys shore flood problem is caused by the inability of the 10.6-mile long westerly outlet channel to discharge sufficient flood flows to keep pace with inflow to the lake during peak periods plus the effect of wind setup and wave runup on low-lying developed areas when lake levels are high.

Beaver Creek flood problems are caused by a combination of a limited flood control capability of Grand Lake St. Marys, poor surface drainage, low stream gradient, constrictions to flow, and high stream stages for a long period of time which cause inadequate outlet conditions for numerous artificial agricultural drains.

Lake water quality has been declining in recent years. Four separate water quality problems have been identified as causing the deterioration. Bacterial contamination from human sources threatens body contact recreation, particularly in areas of greatest development. The rich nutrient content of the lake results in excessive algal growth which causes taste and odor problems. Water clarity is reduced by algae and suspended sediment, resulting in unattractive conditions for recreators. Accumulation of sediment, eroded from upland areas, and unprotected shoreline have reduced the lake depth.

A range of structural and nonstructural flood damage reduction measures were examined. Nonstructural measures investigated for Beaver Creek are not viable solutions because of the agricultural character of the flood plain. Structural measures considered for Beaver Creek including detention basins, diversion, clearing and cleaning, channel improvements, and agricultural levees were determined to be economically infeasible.

Nonstructural flood plain management measures generally will not improve the flood problems for existing structures on the south shore, but regulations adopted by local governments either voluntarily or as required by participation in the Flood Insurance program could be used to reduce damages to future development. Structural measures such as groins and shoreline levees (dikes) are not perceived to be economically feasible. Fixed breakwaters can be effective in reducing shoreline flooding and erosion, but economic benefits are derived primarily from the potential for increased visitation and not from flood damages reduced.

After having examined various alternatives for modifying the operation of Grand Lake St. Marys, it is concluded that the current operating procedures for lake regulation provide an appropriate balance in minimizing flood damage for Beaver Creek and lake shore and in maintaining a desirable recreation pool.

Lake water quality problems related to nutrient and algae control appear better resolved through reduction of nutrient loads to the lake and in particular control of agricultural and livestock waste sources rather than by in-lake treatment approaches.

Emphasis should be placed on the control of erosion and critical soil loss areas in the watershed and unprotected shoreline areas. An extensive lake-wide dredging program, besides being cost prohibitive, would result in no significant improvement in water quality or flood control storage. In-lake dredging of selected near-shore zones as is currently being performed should be continued for improving lake access and boater safety, public land development, and to keep pace with the current rate of sediment accumulation and redistribution.

No recommendations are made for Corps of Engineers construction projects nor is there a specific plan selection for short-term implementation by other agencies. It is recommended that the report be made available to Federal, State, and local government agencies and regional clearinghouses which have an interest in the control and development of water and related land resources in the area affected by the study.

GRAND LAKE ST. MARYS

SURVEY REPORT FOR FLOOD CONTROL AND ALLIED PURPOSES

AUGLAIZE AND MERCER COUNTIES, OHIO

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August 1981

GRAND LAKE ST. MARYS

SURVEY REPORT FOR FLOOD CONTROL AND ALLIED PURPOSES

AUGLAIZE AND MERCER COUNTIES, OHIO

THE STUDY AND REPORT

PURPOSE AND AUTHORITY

The purpose of this study was to investigate flood and related water resources problems and needs of the Grand Lake St. Marys area and describe the various alternatives considered to help solve the problems.

This report has been prepared in response to Section 217 of the Flood Control Act of 1970 (Title II, Public Law 91–611), dated 31 December 1970, concerning flood control and allied purposes, including channel and major drainage improvements, and floods aggravated by or due to wind or tidal effects.

SCOPE OF THE STUDY

Grand Lake St. Marys, the predominant water feature, and its basin, lies in west-central Ohio in the Upper Wabash River Basin. The lake basin drains 119.4 square miles, including portions of Mercer and Auglaize Counties. The study area is divided into two areas: the Grand Lake St. Marys area including tributaries to the lake, and the Beaver Creek area comprised of Beaver Creek and its tributaries.

Several alternatives to help solve flood, and related water resource problems of the Grand Lake St. Marys area, were investigated including those expressed by concerned agencies, the State of Ohio, and local interests. This study was confined to evaluating the advisability and economic feasibility of providing flood control and related resource improvements in the vicinity of Grand Lake St. Marys, Ohio.

STUDY PARTICIPANTS AND COORDINATION

Study participants included concerned Federal, State, and local agencies. Coordination was conducted with the Ohio Department of Natural Resources, Ohio Environmental Protection Agency, U. S. Fish and Wildlife Service, and local agencies. citizens groups, and individuals.

Initial informal meetings were held with State interests on 21 November 1978 and with State and local officials, and local interests on 22 November 1978 in St. Marys Ohio, to provide an opportunity to express their ideas regarding problems and possible solutions in the study area. During the plan formulation stage of investigation, an information brochure was prepared and presented at an informal public meeting held to present alternative solutions studied for flood control, water quality improvement and erosion and sediment control. This meeting was held on 6 November 1980, and was sponsored by the Lake Development Corporation.

THE REPORT

This report is arranged into a main report and three appendices, one of which is a Technical Report. The main report essentially summarizes the Technical Report, but also contains material on plan implementation, coordination, conclusions and recommendations. The Technical Report, Appendix 1, presents more detailed aspects of the study for the technical reviewer. Appendix 2 contains correspondence received as a result of coordination of the draft feasibility report and also contains responses to comments received. Appendix 3 contains reports of others.

PRIOR STUDIES AND REPORTS

The Corps of Engineers has not previously investigated the Grand Lake St. Marys area for flood and water resource problems in the basin, however, a Phase 1 Inspection Report, dated December 1978, was prepared on Grand Lake St. Marys–Western Embankment and Eastern Embankment for the Pittsburgh District as part of the National Dam Safety Program.

The Soil Conservation Service has planned one watershed project. Proposed are 13.3 miles of channel work along Beaver Creek, and one multipurpose flood control–recreation structure on Little Beaver Creek. This project apparently does not have a local sponsor.

The State of Ohio, Department of Administrative Services, Division of Public Works, studied possible diversion of greater flows through the eastern embankment outlet and canal system and also repair measures for the Grand Lake lock, St. Marys Feeder Canal, the Kopp Creek culvert, and the aqueduct over the St. Marys River. The project, as yet, has not been funded for construction.

The Ohio Water Development Authority had a report prepared in June 1977 entitled, "Grand Lake Regional Sewer System Facilities Plan," which was a planning study for the conveyance and treatment of sanitary wastes generated within the Grand Lake Regional Sewer System planning area.

The U. S. Environmental Protection Agency developed information on nutrient sources, concentrations and impact on the lake as part of a report entitled, "Report on Grand Lake St. Marys, National Eutrophication Survey."

RESOURCES AND ECONOMY OF THE STUDY AREA

ENVIRONMENTAL SETTING AND NATURAL RESOURCES

The Grand Lake St. Marys study area is situated in Mercer and Auglaize Counties in west-central Ohio on the low watershed divide between the Wabash and St. Marys Rivers (Maumee River Basin) as shown on the General Map, Plate 1.

Grand Lake is formed by a dam at its west end on Beaver Creek and a dam at its east end on Chickasaw Creek which drains to the St. Marys River via the St. Marys Feeder Canal. The impoundment covers the low watershed divide forming a lake with a surface area of some 21 square miles at approximately 870.5 mean sea level (msl). The lake is approximately eight miles in length east to west and averages over two miles in width north and south with a shore line of approximately 55 miles. Average depth of the lake is 6.8 feet. The total drainage area to the lake is some 112.1 square miles, of which over 18 percent is lake surface. Its principal tributaries are Coldwater, Upper Beaver, Prairie, Chickasaw, Little Chickasaw and Barnes Creeks, all entering from the south. The State of Ohio owns the lake, together with a few small parcels of lakefront property. Lake operation is by the Ohio Department of Natural Resources and the Ohio Department of Public Works.

The Ohio Division of Wildlife operates the St. Marys Fish Hatchery and the Mercer County Waterfowl Refuge at the lake. Several areas along the lake are operated as part of the Grand Lake St. Marys State Park. The lake is surrounded by a combination of agricultural, recreational, permanent and seasonal residential, and urban land uses. Beaver Creek, the western outlet channel, descends gradually through agricultural lands of Mercer County before merging with the Wabash River. Principal urban areas include Celina and St. Marys, with 1980 populations of 9,127 and 8,368, respectively. The study area is approximately 100 air miles due north of Cincinnati, Ohio, and 95 air miles northwest of Columbus, Ohio.

The project study area is in the Tills Plain Section. The topography is gently rolling with elevations ranging from highs of 910 feet NGVD (National Geodetic Vertical Datum) to approximately 850 feet NGVD. The terrain falls generally toward the lake which has a normal water surface elevation of 870.5 feet NGVD.

Land adjacent to Beaver Creek is predominantly Defiance–Wabash soils which are very poorly drained and occupy low lying, level and depressional positions on flood plains. Drainage is difficult to establish due to a lack of suitable outlets resulting from the nearly level topography and prolonged high flows in the main channel. Soils in the Grand Lake St. Marys Watershed are dominantly in the Blount–Pewamo and Blount–Glynwood soil associations. These soils are nearly level to gently sloping, somewhat poorly to very poorly drained silt loam – silty clay loam over loam, or clay loam glacial till. They have poor bearing values in the subsoils and have severe limitations for septic tank systems. With a good drainage system and a high level of management these soils rank as one of the most productive of agricultural products.

The climate of the area is continental with warm summers and is characterized by abundant precipitation, fairly long growing seasons, and wide ranging annual and daily temperature. During January, the coldest month, the average daily temperature is 27° F., and in July, the warmest month, the average daily temperature is 73° F. Average annual precipitation is 37.5 inches, with rainfall distributed fairly evenly throughout the year. Showers and thunderstorms furnish much of the precipitation during the growing season. Heaviest rains occur in June. Frost-free days average 160 days. The normal rainfall is such that lake water level is relatively stable except during drought and heavy rainfall periods.

Grand Lake St. Marys is far from being a clear lake because of algal growth, turbidity and sediment entry. The proportion of pollutants in the lake has been aggravated by increased agricultural development and population growth. Despite the algal condition of the lake, it is a good warmwater fishery and is used exclusively for recreation and as a municipal/industrial water supply.

Much of the land in the Grand Lake St. Marys watershed is agricultural. Mercer and Auglaize Counties are among the most important agricultural counties in Ohio with cash grain farming dominated by corn and soybeans as the major farm enterprise.

Livestock operations (beef, dairy, swine and poultry) are also major farm enterprises, particularly in the lake watershed.

Less than 10 percent of the land in the Grand Lake St. Marys watershed area remains wooded. Forest areas are comprised of small, isolated woodlots surrounded by corn–soybean dominated farming. Travel corridors for wildlife are, to a large extent, limited to stream corridors. Some mammal species remain common, such as muskrat, raccoon, oppossum, fox and gray squirrel, cottontail rabbit and whitetail deer, although destruction of lakeshore wetlands, the removal of fencerows and large woodlots, and residential development has had adverse impacts upon a number of mammalian species. The area has been one of the best locations in Ohio for observing a diverse group of birds. Because of the lake's large surface area and the excellent wetland habitat surrounding the lake, it has become an important concentration area for waterfowl. The area lies within the Mississippi Flyway, a major north–south migratory route for many passerine species. As such, thousands of migratory ducks and geese use the lake as a resting area during spring and fall migrations.

Endangered or threatened species such as the Eskimo curlew, bald eagle, and the American peregrine falcon migrate through Ohio, but sitings in the area are very rare. The range of one endangered mammal, the Indiana bat, is known to include the study area.

There are no documented archeological sites, either prehistoric or historic, in the Grand Lake general study area and no surveys have been undertaken on lands included in the Grand Lake study area; however, undocumented reports have indicated possible sites in or near Celina and St. Marys. There is a high potential for the existence of undocumented prehistoric and historic archeologic sites, especially in the vicinity of the Beaver Creek–Wabash River confluence; lands on a ridge extending towards Erastus along Beaver Creek; lands adjacent to Montezuma Bay; and lands bordering Chickasaw Creek and other creeks tributary to the lake. A total of 248 historically or architecturally significant sites have been documented in the Grand Lake study area. Of these, three are listed in the National Register of Historic Places, one has been nominated to the National Register, and another is in the process of being nominated.

Grand Lake St. Marys came into being as a reservoir to supply water for the Miami Erie Canal. Construction started in 1837 and was completed in 1845 at a cost of approximately $528,000 (Clark, 1960). The then 17,500-acre reservoir was for many years the largest man-made body of water in the world. With a current estimated surface area of 13,920 acres, it is the largest inland water body in the State of Ohio. The lake has a long and interesting history and played an important part in the development of the Northwest Territory. The St. Marys River served as a vital link between the Great Lakes and the Ohio River via the Miami–Erie Canal. The lake once supported a vast commercial fishery. The canal era, however, was short-lived as much of the business of transporting goods was taken over by the expanding railroads. The area experienced another boom in the late 1890's when oil was discovered and for a time the lake was dotted with oil derricks. Today a pile of rocks near the center of the lake marks the spot of the last producing well. The lake has gained growing popularity among recreationists and sportsmen since 1915 when the General Assembly of the State of Ohio passed an act through which this body of water and adjacent lands owned by the State were dedicated and set apart forever for the use of the public, as public parks or pleasure resorts.

Today the lake exists primarily for recreation purposes and is a favorite spot for thousands of vacationists from Ohio and neighboring states. It is also the principal water supply for Celina, Ohio, and St. Marys, Ohio, uses lake water for cooling purposes at their power plant. Primary recreational activities at the lake include boating, fishing, picnicking, swimming, winter sports, and camping. Several areas along the lake are operated as part of the Grand Lake St. Marys State Park. Grand Lake St. Marys Park is located along the northeast shore of the lake and provides recreational activities such as camping, fishing, hiking, picnicking, swimming, and boating. Approximately 500,000 persons visit the park annually. In addition, the Ohio Division of Wildlife operates the St. Marys Fish Hatchery located at the extreme eastern edge of the lake. The Division also operates the 1,400-acre Mercer County Waterfowl Refuge at the southwest section of the lake which provides a haven for migrating as well as nesting Canada geese. Thousands of birds stop at this refuge during spring and autumn migrations.

The lake is fairly heavily used, having at least six major marinas, one State campground, a 4–H camp, and two church camps. Fishermen abound during early spring. Hunters vie for licenses and blind privileges during early winter. There are three public beaches on the lake and hundreds of private beach areas.

HUMAN RESOURCES AND ECONOMIC DEVELOPMENT

Out of 88 counties, Mercer County ranks 56th and Auglaize 51st in Ohio county populations with 1980 populations of 38,242 and 42,461, respectively. While there are no large urban developments in Mercer and Auglaize Counties, those areas that are urbanized are located on or around the Grand Lake St. Marys rim, where most of the population lives. Celina, in Mercer County, and St. Marys, in Auglaize County, are the two most populated areas in the vicinity of Grand Lake St. Marys with 1980 census populations of 9,127 and 8,368, respectively. The Villages of Coldwater (population 4,000) and Montezuma (population 270) are also in the study area.

Between 1950 and 1960 the population of the lake area, including Celina and Franklin Township in Mercer County, and St. Marys and Jefferson Township in Auglaize County, increased by 24.4 percent. This compares to a national increase of 18 percent during the same period. However, from 1960 to 1970, the U. S. population increased by approximately 14.3 percent, while that of the lake area increased by only 8.1 percent. For the total period from 1950 to 1970, the U. S. population rose by 34.9 percent, while the lake area population grew by a comparable 34.5 percent.

From Memorial Day to Labor Day, the seasonal vacation population of Grand Lake St. Marys increases by approximately 20,000 persons, nearly matching the permanent population (23,500).

Most of Celina and St. Marys is residential, with the major portion of homes being single family. The land surrounding the lake is predominantly agricultural and open land except those areas immediately adjacent to the lake. A great portion of the lake's drainage area to the south is classified as prime farmland. The land immediately adjacent to the lake consists of many private and commercial settlements, used mostly for recreational purposes. Cottages, campgrounds, and trailer parks are found around the lake, with highest concentrations on the south side. Adjacent to the lake are several permanent, year-round residential subdivisions.

Land around the lake is presently unzoned, and current growth has been random, with no efforts made to control lot sizes or land use. Consequently, developed land abuts areas of undeveloped agricultural land. Because of its attractiveness for recreational use, the land immediately adjacent to Grand Lake St. Marys is anticipated to be used largely for residential and recreational purposes in the future.

In 1970, the labor force of the two-county study area was 29,068, or about 39 percent of the total population. Of this number, 2.6 percent was unemployed, considerably below unemployment levels statewide and nationally.

The major sectors of employment during 1970 were manufacturing (40 percent), service industries, including government and education (19.4 percent), wholesale and retail trade (19.2 percent), construction (5.3 percent), and agriculture, forestry and fisheries (8.1 percent). Mining activities accounted for less than 1 percent of the two-county work-force. Sizeable increases in the manufacturing, trade, and services sectors, with declining numbers in agricultural, forestry, and fishery occupations are typical of the state-wide employment trends in recent decades.

Agriculture and industry promote a successful economy in the study area. Mercer County is one of the leading agricultural producers in Ohio and ranks second only to Drake County in cash receipts. In 1970 the county contained about 2,000 farms, with acreage totalling over 289,000. Industrial development has also helped Mercer and Auglaize Counties to remain economically sound.

Per capita income in 1970 was $2,450 in Mercer County and $2,668 in Auglaize County. During the decade 1970 to 1980, per capita income was projected to rise to $3,580 in Mercer County and to $3,760 in Auglaize County, or 41 percent in both counties. From 1980 to 2000, per capita income levels are expected to show steady gains of some 74 percent in both Mercer and Auglaize Counties. By 2020, the expected per capita income for Mercer County is $10,116 and $10,626 for Auglaize County. These per capita income figures, unadjusted for inflation, indicate about a three-fold increase in levels between the present and the year 2020 in both counties.

The permanent population of the Grand Lake St. Marys study area and vicinity is projected to increase 34 percent from 21,700 in 1970 to 29,095 by 2000. This compares to a projected State-wide population increase of 24 percent during the same period. The population growth in the urbanized and urbanizing areas of both counties (Celina and St. Marys) are expected to be 14 percent lower (20 percent) than the overall population growth rate of the study area. Permanent population growth along the perimeter of the lake will be limited by space and basic service facilities, yet it is anticipated that the perimeter will support a great deal more than the present population. The summer seasonal resident population is projected to increase 54 percent from 17,600 in 1970 to 27,050 in 2000.

PROBLEMS AND NEEDS

The purpose of this section is to define and discuss the water and resource problems, needs and opportunities in the study area, including the status of existing plans of various Federal and non-Federal agencies and improvements desired by local interests. The study authority has indicated that the major water resource problem to be addressed is flood damages but as is true in most areas, there are general needs and desires for additional outdoor recreational opportunities and enhancement and preservation of the existing natural environment.

STATUS OF EXISTING PLANS AND IMPROVEMENTS

Beaver Creek

A Beaver Creek improvement project has been planned by Mercer County and the State of Ohio. The restoration program encompasses a 10.6-mile reach of Beaver Creek and includes clearing and cleaning the channel of flow restrictive debris and shoals together with reshaping the channel cross section and replacement of tile drain outlets. Beaver Creek was last restored in a similar improvement project in 1951 but was not followed by a regular maintenance program. The project cost estimate of approximately $500,000 was tentatively to be shared equally with $250,000 funding by the State of Ohio and matching funds by the Board of Mercer County Commissioners but the state share, to date, has not been funded.

Soil Conservation Service

The Soil Conservation Service (SCS) constructed three single purpose floodwater retarding structures to provide flood protection to 19 3 square miles of the 125-square-mile watershed of the Wabash River upstream of its junction with Beaver Creek. This PL 566 project named "Upper Wabash Watershed," included about 30 miles of major channel improvement on the Upper Wabash River main stem and tributaries upstream of the city of Fort Recovery. Flood plains not protected by this project include the Wabash River main stem downstream of Fort Recovery to the Ohio Indiana state line and along the entire length of Beaver Creek below Grand Lake St. Marys and was the subject of additional SCS studies. The proposed structural measures include a multiple purpose flood prevention water quality control structure, a multiple purpose flood prevention recreation structure, two miles of multiple purpose flood prevention drainage channel with six drainage pumps, and 13.4 miles of flood prevention channel improvements (Beaver Creek). Costs were estimated at $4,136,500 (1969 dollars) but the project has not been constructed because of lack of a local sponsor.

Grand Lake Regional Sewer System

This is a Public Law 92-500, Section 201 project for U.S. EPA construction grants to build a $14 million-plus, sewage collection and sewage treatment plant expansion and upgrading system for portions of Mercer and Auglaize Counties immediately adjacent to the lake. The original plan divided the lake area sewer system into two portions at the Mercer Auglaize County line and conveys the Auglaize County flow to the existing St. Marys wastewater treatment facility and the Mercer County flow to the existing Celina wastewater treatment facility. The primary objective of this plan is the protection of Grand Lake St. Marys by elimination of human waste loads to the lake, especially the high coliform content.

The project has met with local opposition because of high costs. The Farmers Home Administration and U.S. EPA have tentatively withdrawn loan or construction grant approval pending additional studies and review for a modified lower-cost project or other alternative wastewater management plans.

Grand Lake/Miami and Erie Canal

The Ohio Department of Administrative Services, Division of Public Works, has had prepared a plan to provide greater flow capacity through the St. Marys feeder canal (the Grand Lake eastern outlet channel) together with significant repair of the eastern embankment lock structure, the Kopp Creek culvert, and the aqueduct over the St. Marys River. A major part of the plan calls for lowering the east spillway crest elevation to that of the west spillway crest elevation in order to "provide an east/west split of uncontrolled discharge capacity which is proportional to the drainage areas contributing runoff to the lake." To date the $951,500 improvement project has not been funded for construction.

FLOOD PROBLEMS

Flooding has been reported for years, not only around Grand Lake St. Marys, but also along Beaver Creek, the lake's natural outlet channel. Periodic flooding of primarily agricultural land along Beaver Creek is attributed to a combination of factors including a very limited flood control capability of Grand Lake St. Marys, poor surface drainage, low stream gradient (1.5 feet per mile), high stream stages which cause inadequate outlet conditions for numerous artificial agricultural drains, and constrictions to flow from vegetation on the banks, shoals, and debris throughout the entire 10.6-mile reach. Flooding problems along Beaver Creek are from both overbank inundation and subsurface saturation as a consequence of long periods of near bankful flow in the flat gradient channel. Peak discharges from the lake's western outlet are not great enough to cause instantaneous flooding, and are less than would be experienced without the lake. However, it often requires several weeks of steady outflow to pass flood runoff from the lake. This condition is sufficient to keep Beaver Creek near bankfull for long periods of time and is damaging to agricultural operations, particularly in the spring and early summer in the flood plain.

Periodic flooding occurs along the south shore of the lake where the topography and developments are generally at a low elevation. The flooding is attributed to many factors including poor natural drainage plus a high water table, and to a high lake level combined with wind-induced wave action which causes water to runup on the shore with subsequent damage to residential buildings and contents. In most years, the lake level does not exceed one foot above west spillway crest (870.75 NGVD), but this rise is sufficient to cause flood damage on the south shore when the effects of wind setup, seiche effect and wave runup are considered. The recreation-oriented developments around the lake tend to make any lowering of the water surface undesirable.

Lake pool elevation 871.75 was identified as the water surface elevation, together with wind-induced wave action where lake shore flooding begins.

Limited data has restricted the analysis of historical flood events. However, the storms which occurred in March 1913, and were centered near Bellefontaine, Ohio, produced the flood of record for a majority of long-term gaging stations in both northeastern Indiana and southwestern Ohio. The 5-day rainfall total was 11.1 inches at Bellefontaine which is approximately 40 miles southeast of Grand Lake. Available water surface elevation records for the Grand Lake pool began in March 1927 and provide an indication of additional flood periods. The maximum pool level of recorded data occurred on 15 January 1930 at elevation 872.83. The Ohio Division of Parks and Recreation records also note an absence of gate operations during this high water period. This lack of outlet openings produced the maximum attainable pool structurally possible from available inflows. The peak lake inflow, during the period of recorded data, was estimated to be nearly 12,000 cfs. This event occurred on 18 May 1927 and was the result of a high intensity storm of short duration and low volume. This storm produced a peak pool elevation of 871.75 feet NGVD.

Table 1 presents 11 of the 12 observed annual events which exceeded elevation 871.75 for the period of record. Seven of the 12 events occurred during the recreation season.

Local residents and farmers along Beaver Creek were interviewed and reported significant flood events during January 1949, December 1957 through January 1958, March through April 1964, March 1965 and May 1972. Several lesser floods were reported during the June through November months when crop losses are greatest. No gaged data of historical floods are available for Beaver Creek.

TABLE 1

HISTORICAL LAKE POOL ELEVATIONS

Observed Data

Date	Peak Pool Elevation	Days Above Elev. 871.75	Peak Mean Daily Outflow
	(feet)		(cfs)
Jan 1930	872.83	18	300
May 1943	872.67	24	330
Apr 1972	872.67	32	310
Apr 1938	872.42	19	550
Feb 1950	872.42	24	520
Apr 1978	872.17	37	380
Jan 1949	872.08	19	260
Apr 1957	872.08	23	550
Jun 1958	871.92	11	380
May 1933	871.92	5	490
Nov 1972	871.92	9	510

Flood Damages

The areas under consideration include Beaver Creek downstream from the lake and portions of the developed lake shore. The extent of flood damages has been identified by developing hydrologic and field data which considered such aspects as stream characteristics, lake releases, extent and character of the drainage basin and flood plain, projected future characteristics in the case of Beaver Creek and lake levels, wind and wave action and character of shoreland in the case of southshore flooding. These data were used in developing estimated present and future flood damages. Damages were developed for stream reaches and developed shoreland areas shown on Plate 2 in order to identify damage centers.

The Beaver Creek flood damage study extends from its confluence with the Wabash River upstream to the western outlet of Grand Lake St. Marys, a stream distance of about 10.6 miles. Table 2 shows the monetary damages that could be expected to result from the occurrence of three specific flood events (a flood that occurs on the average of once in 5 years, a flood that occurs on the average of once in 10 years, and a 100–year frequency flood). Table 3 provides the average annual equivalent damages that can be expected for each stream reach.

The southshore flood damage study area extends from west of Montezuma Bay (Zeb's Landing) eastward to Barnes Creek (Southmoor Shores) and includes most of the shoreland development in between. Flood damages for the lake shoreline area are attributed to a high lake level combined with wave action and wind setup.

Flood damage surveys were made for selected residences along the shoreline areas. Commercial establishments were not evaluated since most are located either at elevations out of reach of flooding or sufficiently distant from the shore, such that damages are virtually non-existent. The total value of all residences along the southshore is estimated to be $6,000,000. Present annual damages to residences in the form of structure and content damage are estimated to be $150,200 for approximately 142 private shoreline properties (Table 4).

TABLE 2

DAMAGE FOR OCCURRENCE OF SELECTED FLOOD HEIGHTS
BEAVER CREEK, MERCER COUNTY, OHIO
(1980 Conditions and Price Levels)

Reach	Upper Limit of Reach: Geographic	Upper Limit of Reach: Stream Mile	Item	Damage for Specific Flood Height ($1,000): 5-Year	10-Year	100-Year
BC–1	Gause Road Bridge	4.75	Acres	865	985	1,401
			Crop	12.7	14.4	18.3
			Noncrop	9.9	17.6	21.6
			Transportation Facilities	1.5	2.5	8.1
			Public Utilities	5.5	7.1	9.1
			Subtotal Damages	29.6	41.6	57.1
BC–2	Grand Lake Western Embankment	10.6	Acres	1,250	1,338	1,833
			Crop	18.3	18.9	21.6
			Noncrop	2.4	4.0	10.6
			Transportation Facilities	1.4	3.1	11.9
			Public Utilities	2.3	4.3	15.4
			Subtotal Damages	24.4	30.3	59.5
TOTAL ALL REACHES			Acres	2,115	2,323	3,234
			Crop	30.9	33.2	40.0
			Noncrop	12.3	21.6	32.2
			Transportation Facilities	2.9	5.6	20.0
			Public Utilities	7.8	11.4	25.1
			TOTAL	53.9	71.8	117.3

TABLE 3

AVERAGE ANNUAL DAMAGES
BEAVER CREEK
(Present 1979 Conditions)

Damage Category [2/]	Reach [1/]		Damage Totals
	BC-1	BC-2	
Crop	$30,850	$32,350	$63,200
Non-Crop	9,700	3,200	12,900
Transportation Facilities	1,400	1,310	2,710
Public Utilities	3,950	2,240	6,190
Totals	$45,900	$39,100	$85,000

1/ See Plate 2.

2/ Crop – for major crops produced; corn, soybeans and hay
Noncrop – agricultural properties such as siltation of tiles, debris removal, land erosion and repair, surface ditch maintenance, farm roads and levees.
Transportation facilities – roads, fills, bridges, culverts
Public utilities – after flood maintenance of telephone, gas and electric, and other public utility services.

TABLE 4

AVERAGE ANNUAL DAMAGES
SOUTH SHORE OF
GRAND LAKE ST. MARYS

Location 1/	Estimated Number of Properties Subject to Damages	Estimated Annual Damages 2/
1	10	$ 10,680
2	31	32,500
3	39	42,610
4	14	14,940
5	6	6,900
6	18	15,750
7	12	15,000
8	7	7,480
9	5	5,340
Totals	142	$150,200

1/ See Plate 2
2/ Structure and contents damage

WATER QUALITY PROBLEMS

Based on local observations and on actual data collected on Grand Lake St. Marys, lake water quality has been declining in recent years. This can be seen through increased siltation and algae blooms. Previous studies have shown that the primary contributors to the decline in lake water quality are from phosphorus and sediment. As the water quality declines, the quality of the recreational experience the lake will support will also decline.

The Grand Lake St. Marys area has been the object of several water quality related studies in the past few years. The lake is used primarily as a recreational facility and is administered by the Ohio Department of Natural Resources. Its recreational uses include boating, fishing, and body contact water activities such as skiing and swimming. Another important use is as a water supply source for the City of Celina.

The lake is classified as an exceptional warm water habitat, a public water supply, and as bathing waters. Its tributaries are classified as warm water habitats.

Because the lake has three designated uses, no one set of State water quality criteria is exclusively applicable to it. In the case where several sets of criteria exist for the same body of water, the most stringent criteria apply.

The water quality of Grand Lake St. Marys has been examined in connection with its eutrophication problems. The lake experiences massive algal blooms several times each year, and taste, odor, and fish-tainting problems with the water have been reported frequently. In a survey conducted by the U.S. Environmental Protection Agency on Grand Lake St. Marys, algal productivity was found to be phosphorus-limited during the spring and summer and nitrogen-limited in the fall. The estimated phosphorus loading of the lake (0.49 $g/m^2/yr$) was 1.8 times greater than the commonly accepted eutrophic loading limit of 0.28 $g/m^2/yr$.

In addition to the U.S. EPA study, the Mercer–Auglaize Environmental Research Association monitored water quality in the Grand Lake St. Marys area from 1973 to 1975 at ten locations. In general, the data support the high nutrient loadings found during the U.S. EPA study, but it also indicated significant bacterial pollution of the lake. The average fecal coliform concentrations from 1972 to 1975 exceeded the state water quality criteria for bathing waters (200 coliform/100 ml) at all ten sites sampled. A Master's thesis by James P. Loughran (1973) entitled, "The Analysis of Tributary Outfalls as Possible Sources of Micro–biological Contamination of Grand Lake-St. Marys," concluded that the bacterial pollution of the lake was severe enough to warrant action discouraging its use for primary body contact recreation. Data presented in this thesis indicated that bacterial contamination of the lake was from both human and animal sources, although the relative magnitude of each of these sources was not identified.

The bacterial contamination of the lake has been attributed to the Mercer Wildlife Refuge on Montezuma Bay; however, considering the large number of persons that visit the lake annually and the extensive use of septic tanks in many unsuitable areas along the south shore, it is probable that a large part of the lake's microbiological contamination is due to human waste.

Severe taste and odor problems have been reported with the water of Grand Lake St. Marys. People living around the lake frequently complain of a musty odor in the air and the City of Celina experiences taste and odor problems with both the raw water it withdraws from the lake and with finished water distributed to its customers. Odorous compounds of biological origin known to taint water supplies were reported by A. A. Rosen, et. al in 1970 as being found in Grand Lake St. Marys. These compounds include geosmin and 2–methylisoborneol, which are produced by certain strains of actinomycetes. Although geosmin is characteristically associated with the musty odor of heavy algae blooms in reservoirs, data indicated that 2–methylisoborneol constituted 68 percent of the odor from Grand Lake. In a 1964 taste and odor study of Celina's water supply (Grand Lake) conducted by Finkbeiner, Pettis & Strout, Ltd. algae, either directly or indirectly, were identified as responsible for the majority of the taste and odor problems.

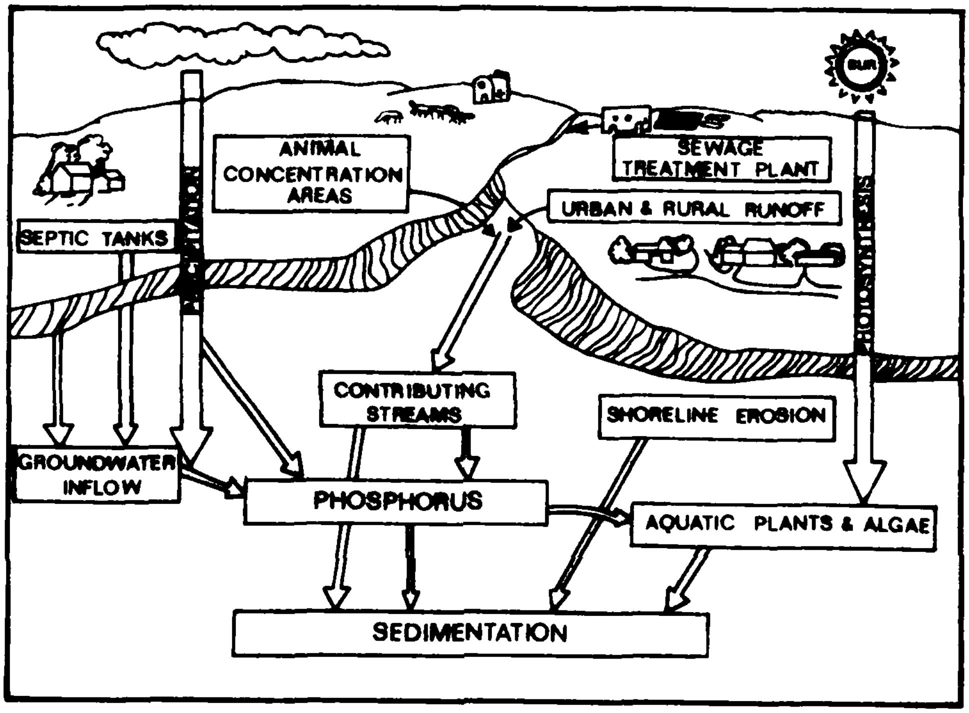
More recent studies undertaken by Finkbeiner, Pettis & Strout, Ltd. in August 1980 on Grand Lake St. Marys centered on water quality adjacent to greatest development and on parameters indicative of human wastes. The investigation confirmed previous studies of lake pollutant loadings and showed that human wasteload originating from lake shore development continues to degrade lake water quality. Bacterial counts confirmed the presence of sewage, creating a problem which at peak use periods affects the entire lake.

In summary, the primary water pollution problems in Grand Lake St. Marys is the eutrophication of the lake as described above. The main water quality problems are associated with nuisance algae blooms and inadequate sewage treatment. Taste and odor problems in the lake have been linked to the algae blooms, which also interfere with recreation and water supply uses. Other information indicates significant bacterial pollution of the lake.

Other than in Grand Lake St. Marys, water pollution problems are associated with Beaver Creek. During dry periods, the flows in the upper reaches of Beaver Creek essentially cease and the only flow in Beaver Creek is the effluent from the Celina wastewater treatment plant. This has resulted in serious water quality problems in the creek, including high levels of suspended solids and nutrient concentrations and low dissolved oxygen. Facilities plans are presently being prepared for improvements to the Celina wastewater treatment plant that will alleviate this problem.

Sources

The drawing below shows a conceptualization of phosphorus and sediment pollution sources which contribute to lake water quality problems.



Phosphorus input sources have been categorized as either "point" or "non-point" sources for purposes of estimating total annual phosphorus loadings to the lake.

Point sources are those which discharge effluent at known locations and include one municipal sewage treatment plant (St. Henry) and 17 small premanufactured (package) treatment plants surrounding the lake, each of which discharge effluent with varying degrees of treatment directly or indirectly to the lake.

Non-point sources include phosphorus from such diverse sources as precipitation, agricultural and livestock areas, waterfowl, septic tank-soil absorption systems, and direct urban and suburban runoff. Phosphorus contained in rainwater falling directly on the lake surface is generally uncontrollable and the ability of algae to utilize the phosphorus is still in question with researchers. Cropland and animal concentration areas (feedlots) both contribute nutrients and sediments through runoff and erosion. The high concentration and number of waterfowl at Grand Lake has been suspected of contributing phosphorus and bacterial contamination of the lake. Although the concentration of septic tank-soil absorption systems around the lake is generally known, they are considered non-point sources because pollution from them seeps into the lake over a dispersed area. Urban and suburban runoff contributes pollutants after rainfall events from residential areas and streets.

Finally, erosion of watershed lands, streambanks and shoreline contribute sediments which cause turbidity and phosphorus-bound particulate matter which causes the proliferation of odor and taste-producing algae throughout the lake.

Annual Phosphorus Loads

It is estimated that approximately 33,000 kilograms of total phosphorus are currently contributed to Grand Lake on an annual basis. The estimated phosphorus loading rate of 0.49 gram per meter square per year to the lake is nearly 1.8 times greater than the commonly accepted loading limit. This means that Grand Lake St. Marys can be considered eutrophic. The excess nutrient concentration results in increased biological activity and culminates in nuisance algal growths, reduced oxygen content, and noxious tastes and odors. With these conditions the lake may become unacceptable as a source of water supply and recreation.

Of the total phosphorus loading, it is estimated that, on the average, approximately 15,000 kilograms are removed from the lake annually via Beaver Creek and the St. Marys Feeder Canal. At the current estimated rates of phosphorus input and output, approximately 18,000 kilograms of the total phosphorus accumulates annually in the lake.

Several sources of phosphorus which were thought to be significant, specifically septic tank systems and waterfowl, are contributing only small quantities of phosphorus to the lake.

The estimated percentage contributed by each source is identified in Table 5. The most significant contribution of phosphorus to Grand Lake St. Marys and to the rapid rate of eutrophication of the lake appears to be from non-point sources or rural, primarily agricultural land and livestock concentration areas.

TABLE 5

ESTIMATED ANNUAL
TOTAL PHOSPHORUS LOADINGS FROM SPECIFIC SOURCES
GRAND LAKE ST. MARYS, OHIO

Source	Kilograms	Percentage of Total
Precipitation	780	2.3
Waterfowl (Geese)	216	.6
Animal Concentration Areas (Feedlots)	7,500	22.6
Agricultural/Rural Land	21,000	62.9
Municipal Point Source (St. Henrys)	1,449	4.3
Domestic Point Sources	746	2.2
Septic Tank-Soil Absorption Systems	610	1.8
Direct Urban and Suburban Runoff	1,088	3.3
Totals	33,389	100.0

EROSION AND SEDIMENT PROBLEMS

Soil erosion and sedimentation pose major problems to lakes and streams. In bulk, sediment is the greatest single water pollutant nationwide and is no exception at Grand Lake St. Marys. The introduction of sediment to the lake occurs as part of natural watershed processes. However, man's activities which have dictated the land use and manipulated the vegetative cover have greatly accelerated this process over a long period of time by removing protective vegetation from the watershed. The effect of erosion-induced sediment accumulation in the lake is realized in many ways. Physically, turbidity caused by suspended and resuspended sediments decreases light penetration and thereby affects photosynthesis which in turn may reduce oxygen production. Sediment accumulation is suspected of destroying fish spawning areas; curtailing recreational activities, especially boating; reducing aesthetic values; and creating shallower areas which cause an increase in biological activity. Besides the physical effects of sedimentation, fine-grained suspended solids composed predominantly of clays have a high absorption capacity. Sediments may bind or immobilize pollutants and remove them from the water. On the other hand, if the sediments are overloaded with pollutants, they may be released to the water column. In the Grand Lake St. Marys watershed, most soils being of the silty clay loam type would absorb pollutants, particularly phosphorus carried to the lake. The release of these nutrients can also be increased when bottom sediments are stirred up by power boats, carp and other bottom scavengers. Evidence exists which supports the occurrence of these changes at the lake.

Erosion has been identified in six categories of concern to lake users: farm drainage erosion, streambank erosion, lake shoreline erosion, channel erosion, island erosion and dredge spoil erosion.

Farm Drainage Erosion

Erosion of the soils in the lake's watershed consists of moderate sheet erosion. Nearly all waters observed entering the lake have considerable amounts of suspended silt. Watershed erosion from primarily agricultural lands, includes washoff of soils and farm chemicals dissolved in the runoff. Soil erosion creates economic problems because fertile soil and components are depleted from the surface. Soil erosion creates environmental problems because suspended and dissolved solids affect water quality, sedimentation and shallowing of the lake, and bottom dwelling organisms. Significant improvements in lake water quality are tied to reducing suspended sediment loading from the lake's agricultural drainage basin.

Streambank Erosion

Streambank erosion occurs in the study area although this type of erosion is considered moderate. Soils notable for erosion problems – Blount and Glynwood – occur throughout the lake watershed. The most notable streams having erosion problems include Coldwater, Burntwood, and Chickasaw Creeks. Coldwater Creek banks have developed serious erosion problems due to runoff scour which increases sediment load delivered to the lake.

Lake Shoreline Erosion

Lake shoreline erosion is caused by a number of factors including wind-driven waves, boat wake attack, high water, and winter ice. In general, the north, east and west shores of the lake have adequate bank protection through use of seawalls and riprap. Although a few exceptions are noted along inlet channels and embayments, shoreline erosion problems are limited to the southshore. It is reasonable to state that developed shoreline is protected and undeveloped shoreline is not. Bank erosion along the undeveloped southshore areas is the most dramatic in the study area, with approximately 5-foot vertical drops and uprooted trees observed nearly throughout. Some riprapping of these mostly State-owned areas has been undertaken, but the success of any such program is limited by access problems and funding. The rate of shoreline erosion has not been quantified because of a lack of long-term survey data; however, the amount of unprotected shoreline is estimated at 60,000 linear feet, or 11.3 miles. This represents some 23 percent of the total lake shoreline.

Channel Erosion

This erosion problem results from a combination of factors and affects boat channels, boat basins, and natural inlets in the lake. The shallow depth makes the channel banks susceptible to wave scour. Rapid surface runoff erodes soils and results in silt deposition in natural inlets. Prop wash and boat wakes, together with a general lack of coarse gravels and rock or bottom vegetation contribute to the erodibility of channels and other bottom features.

Island Erosion

Existing islands in the lake are especially susceptible to ice and wave-induced erosion because of their small size and exposure from any side. Except for Safety Island, most all island formations are generally unprotected from these effects. The contribution of sediment to the lake is considered minor compared to other erosion sources, but they are the most susceptible to erosion and should be preserved for their intended long-term use as waterfowl areas.

Dredge Spoil

Dredged spoil material placed in unprotected rows and left unprotected erodes quickly back into channels and into other parts of the lake. Unprotected dredge rows are suspected of contributing sediment back into the lake and channels where turbidity is increased for long periods of time. Contained spoil areas for dredge materials are warranted in a large water body such as Grand Lake St. Marys which is subject to high wind and wave activity.

Summary

Erosion of the unprotected shoreline, streambanks, and upland areas in the watershed contributes to the rate of sediment accumulation in the lake. The estimated annual loading of sediment to Grand Lake St. Marys from tributary streams and upland areas is approximately 26,000 tons. No estimate was made as to the amount of eroded shoreline island or dredge spoil material which accumulates in the lake annually.

Although sedimentation does not appear to be seriously depleting the lake storage, the material accumulates in places where it is especially noticeable and troublesome. Sediment accumulations are most prevalent around the perimeter of the lake where water velocity is low. The combination of shallow water and wind-induced wave action creates circulation patterns capable of eroding and transporting sediments in the lake.

The general problem categories of flooding, lake water quality, and erosion/sedimentation impact on several other water-related problems that exist at the lake. These include: shallowness, siltation, taste and odor, and wind and wave problems, all of which impact on the quality of the recreational experience, water supply, and fish and wildlife resources.

FISH AND WILDLIFE NEEDS

According to the U. S. Fish and Wildlife Service the natural productivity of desirable fish and wildlife resources has declined at Grand Lake St. Marys over the last 75 years. During the early years up to 1900 the lake was used as a very successful commercial fishery with dominant fish being black bass, sunfish, perch and catfish. Between 1890 and 1900, several droughts lowered the lake level considerably causing heavy fish kills, stump and snag removal, and the disappearance of aquatic vegetation. When the lake refilled after the drought, wave action and turbidity increased and the lake changed from a relatively clear, cool body of water to a turbid, warmwater area with increased wave action. The fish population changed to less desirable species (carp, white crappie, bullhead and channel catfish). Since the time the lake was turned over for recreational purposes, in the 1930's, many attempts were made to improve fish habitat, and in recent years fishing has improved greatly. Several decades of intensive efforts were made to replicate earlier conditions which contributed to the lake's excellent fishery resources. This included regulation of angling during spawning seasons, rough fish removal, stocking of fish, and habitat improvement. Despite these efforts, returning the fishery population to its former condition has not been accomplished.

Since the formation of Grand Lake St. Marys, the changes of the fishery population has been as drastic as the changes which occurred to its aquatic environment. With a more degraded condition of water quality and diminished fishery habitat, populations of more desirable sport fish have decreased. Nevertheless, a good warmwater fishery is maintained which provides fishing enjoyment for many thousands of sport fishermen.

Current wildlife habitat populations in the Grand Lake St. Marys area are very much dependent on cover and nesting habitat. Intensive farming in the watershed has resulted in the destruction of necessary habitat to maintain a high density of upland wildlife. The area still provides adequate wetland habitat to make it important for waterfowl population, but this condition must be maintained or enhanced.

With continued development around the lake, the quality and quantity of the existing resource base is expected to erode. The problem is complex; however, degraded water quality and degraded fish and wildlife habitat are two key factors which account for the resource losses. The U. S. Fish and Wildlife Service further concludes that associated wetlands are vital segments in Grand Lake's resource production and perpetuation and will be further jeopardized if reduced or committed to non-resource use.

GENERAL RECREATION NEEDS

The State of Ohio Comprehensive Outdoor Recreation Plan indicates significant deficiencies in realizing the recreational potential for boating, camping, sailing, swimming, and picnicking in the Mercer and Auglaize County area. The Plan, for example, states that the study area "has not developed its full potential because of lake siltation and pollution problems, lack of adequate lands to balance water area and unconsolidated land ownership surrounding the lake." Although a large portion of the lake's 50-mile shoreline has been developed for water–associated recreation, including lakeside residences, public and private beaches and docks, and public park areas, a comparison of visitor numbers at other lake facilities in a 60-mile radius region generally indicates that Grand Lake St. Marys is underutilized. A smaller than usual amount of boating occurs for such a volume of water as this. The reasons are many and varied, but water-related problems including shallowness, siltation, pollution, submerged objects, odors and wind and wave problems create difficulties with the existing and potential recreational use. Lowering of the lake level, for any reason, is considered a detriment by recreation interests. As discussed in "Water Quality Problems" another detriment to recreation is the periodic growth of blue-green algae in Grand Lake St. Marys.

Review of other study area problems and needs indicated that there was a need to include opportunities for improvement, restoration, or enhancement of overall water quality of the lake as a planning objective as well as erosion control and sedimentation control. All of these objectives are oriented toward enhancing and increasing the potential of water-oriented outdoor recreation opportunities.

IMPROVEMENTS DESIRED

State and local officials and organizations have from time to time since 1970 expressed, through meetings, correspondence, and minor reporting efforts, their desires for improvements to problems in the areas of flood control, drainage, water quality, erosion and water-related recreation. Local interests cite lake water quality problems including adverse odor and taste caused by frequent widespread blue-algae blooms, severe wave action, shallow lake water depths, and erosion as problem areas of primary concern. The State of Ohio, Department of Natural Resources, has indicated that erosion control, pool level control, and nutrient-algae control are the State's primary concerns as related to the lake's primary purpose which is water-related recreation. Local concerns would like to have the water quality improved and the lake level stabilized to enhance recreation potential and control flooding of portions of the lake perimeter. Downstream farmers along the lake's western outlet channel, Beaver Creek, seek relief from periodic field flooding caused by restrictive channel conditions, low stream gradient, inadequate tile outlets and releases from the lake.

PLANNING OBJECTIVES

The primary objectives of this survey investigation were to report to Congress an inventory of the publicly identified water and related resources problems and needs in the study area and to investigate a range of feasible alternatives for resolving water-related problems that may be implemented individually or collectively by local, state, and Federal agencies. The general overall objective is to determine what, if any, feasible, economic measures could be undertaken to restore and enhance Grand Lake St. Marys and its environs as a viable water resource.

For the Beaver Creek and lake shore area, specifically, planning objectives were established to provide for problems and needs which were identified. The authorization for this investigation made particular reference to the flood problems at Grand Lake St. Marys. Therefore, flood control for the south side of the lake and for Beaver Creek was established as a primary planning objective.

FORMULATION OF ALTERNATIVES

The following section is intended to identify and discuss the range of alternatives considered for the three general problem categories of flooding, lake water quality and erosion/sedimentation and the two main problem areas: Beaver Creek and Grand Lake St. Marys. Each alternative discussion contains information where applicable on: description, impacts and effects, costs, economic data and comments on economic, technical, and institutional feasibility. Table 6 is the list of possible measures initially developed. The first subsection, Initial Screening, offers comments on those alternatives which have not been given detailed consideration. The second subsection offers a summary of alternatives worthy of more detailed consideration.

INITIAL SCREENING

Beaver Creek Flooding

Natural Impoundments (Alternative IA.3).

Few natural impoundments exist, either naturally or as might be modified, outside of Grand Lake St. Marys itself, to retard peak flows entering from the uncontrolled drainage area of Beaver Creek. Therefore, this alternative was given no further consideration.

TABLE 6

ALTERNATIVES CONSIDERED

I. DOWNSTREAM FLOODING (BEAVER CREEK)

A. Measures to Modify Flooding Prior to Reaching Critical Damage Areas

1. Detention Basins in Lake Watershed
2. Diversion to St. Marys River via Fourmile Creek
3. Natural Impoundments (NS)
4. Weather Modifications (NS)
5. Lake Regulation

B. Measures to Modify Flooding at Critical Damage Areas

1. Channel Modification
   a. Clearing, Cleaning and Snagging
   b. Channel Enlargement
2. Agricultural Levees
3. Pre-Flood Emergency Action (Flood Fighting) (NS)

C. Measures to Modify Actual Damages (Prevention)

1. Flood Proofing (NS)
2. Permanent Evacuation (NS)

D. Measures to Modify Individual Economic Losses while Permitting Major Damages

1. Flood Forecasting and Temporary Evacuation (NS)
2. Flood Insurance (NS)

II. LAKESHORE FLOODING

A. Measures to Modify Flooding Prior to Reaching Critical Damage Areas

1. Detention Basins in Lake Watershed
2. Diversion to St. Marys River via Fourmile Creek
3. Spillway/Outlet Modification
4. Natural Impoundments (NS)
5. Lake Regulation (NS)

B. Measures to Modify Flooding at Critical Damage Areas

1. Reduce Wind Set-up (Breakwaters, Groins)
2. Protect Low-Lying Areas (Shoreline Levees)

C. Measures to Prevent Actual Damages

1. Flood Proofing (NS)
2. Permanent Evacuation (NS)
3. Structure Relocation (NS)
4. Flood Proofing Future Structures (NS)
5. Flood Plain Management-Future Development

D. Measures to Modify Individual Economic Losses while Permitting Damages

1. Temporary Evacuation (NS)
2. Flood Insurance (NS)

III. LAKE WATER QUALITY IMPROVEMENT

A. Measures to Reduce Nutrient Inflow (External Source Controls)

1. Treatment of Wastewater Inflows (Point Source Controls)
2. Control of Non-Point Sources
   a. Agricultural Land Management
   b. Livestock Waste Management
   c. Runoff Treatment
   d. Other Non-Point Source Controls

B. Measures to Disrupt Internal Nutrient Cycles (In-Lake Controls)

1. Dredging
2. Destratification/Aeration
3. Nutrient Inactivation/Precipitation
4. Dilution/Flushing
5. Drawdown
6. Lake Bottom Sealing

C. Measures to Accelerate Nutrient Outflow

1. Biotic Harvesting of Algae, Aquatic Plants, Rough Fish

D. Measures to Control Erosion and Sedimentation

1. Shoreline, Streambank and Watershed Erosion Control Measures
2. Sedimentation Ponds

NS – refers to nonstructural protection measures.

Weather Modifications (Alternative IA.4).

The effectiveness of identifying and then modifying potential storm centers is not sufficiently accurate at this time to warrant further consideration.

Pre-flood Emergency Action (Alternative IB.3)

There are no established physical emergency actions that can be effectively employed by landowners because potential flooding problems are not localized, but extend throughout the Beaver Creek reach.

Flood Proofing and Permanent Evacuation (Alternative IC.3,-.4).

Since few structures are located along the Beaver Creek reach and none are affected, this alternative is not an alternative to the primarily agriculturally-related flood problems.

Floodplain Zoning, Land Use Regulation (Alternative IC.3).

These alternatives offer little opportunity by themselves along Beaver Creek since major damages occur to cropland and no change or variance in this existing land use is expected in the future.

Flood Forecasting and Temporary Flood Evacuation (Alternative ID.1).

Flood forecasting information is and will continue to be used in the Beaver Creek reach, but the predictive capability of the method in a drainage/lake system such as exists at Grand Lake St. Marys makes this an ineffective solution in reducing flood damages. Temporary evacuation is not a realistic solution to rural, agricultural flood damage problems.

Flood Insurance (Alternative ID.2).

Insurance does not prevent flood damage or future losses, but indemnifies a policy holder for financial losses suffered during a flood. Insurance available through the National

Flood Insurance Program does not cover growing crops, or livestock, and therefore is not available for agricultural crop damages. The Federal Crop Insurance Act of 1980 (FCIA), however, offers farmers new alternatives for reducing crop production risks from natural disasters such as flooding. For the 1981 crop year farmers may elect Agricultural Stabilization and Conservation Service (ASCS) disaster payments, Federal Crop Insurance Corporation (FCIC) payments, or both, depending upon whether their FCIC premiums are subsidized. Beginning in 1982 the ASCS disaster payment program will be discontinued. Disaster payments will be replaced by a crop insurance program which permits farmers to select the level of protection desired and pay a corresponding premium. Mercer and Auglaize Counties will offer the new crop insurance program in 1981 and 1982. Since this Federal program is available to affected farmers, no further evaluation is necessary in this study.

Lake Shore Flooding

Natural Impoundments (Alternative IIA.4).

Few natural impoundments exist either naturally or as might be modified to retard peak flows entering from the lake's watershed. Those that do exist have insufficient capacity to result in flood damage reduction to lake shore property.

Floodproofing Existing Dwellings (Alternative IIC.1).

This involves the modification of dwellings by waterproofing or raising them to prevent floodwater intrusion. Waterproofing measures such as closures and wall structures placed in contact with affected frame-type dwellings are not considered practical or effective protection from the hydrostatic and uplift pressures exerted by waves nor would they provide a secure watertight seal for the crawl space and dwelling at and above the first floor elevation. It has been determined that due to the expense and scope of the requirements inherent in waterproofing, it is also not cost effective as a primary solution.

Permanent Evacuation (Alternative IIC.2).

This alternative involves the purchase of all properties affected, which at the flood damage level, involves some 131 to 142 properties. The alternative was found to be undesirable and economically infeasible. It would require abandonment of desirable shoreline property. The economic analysis showed unfavorable benefit-to-cost ratios of 0.48 and 0.45 with and without conversion of vacated lands to recreation, respectively, making the alternative economically impractical.

Structure Relocation (Alternate IIC.3).

This alternative was eliminated from further consideration since, even though most dwellings are relocatable, most effected structures are not primary dwellings, the desirable recreation objective would be lost and unfavorable benefit-to-cost ratios of 0.77 and 0.76 resulted with and without conversion to recreation, respectively.

Floodproofing Future Facilities (Alternative IIC.4).

As will be discussed below, Mercer County, as a participant in the National Flood Insurance Program, will be required eventually to adopt ordinances or other controls to regulate land use and construction within the 100-year flood plain (land area inundated once per hundred years, on the average). With this alternative, future development would additionally be required to be floodproofed to the level of the standard project flood, which is a flood representing the critical flood runoff volume and peak discharge that may be expected from the most severe combination of meteorologic and hydrologic conditions that are considered reasonably characteristic of the hydrologic region involved. Floodproofing would consist of elevating future buildings on pads or piles, constructing dikes, providing watertight closures and anchorage systems, waterproofing, or using any such method designed to resist inundation. Because expenses would be borne by individual property owners, the increased costs of floodproofing may tend to discourage development in the flood plain. This plan, however, would not protect existing development, and the economic and individual costs of floodproofing new and replacement structures may prove to be excessive.

Temporary Evacuation (Alternate IID.1).

This alternative, while questionable in regard to levels of damages prevented or reduced, does offer a principal means of protecting the personal safety and personal property aspects of risks associated with the type flooding at Grand Lake St. Marys. To be effective, a flood warning system, which gages the critical parameters of lake levels, wind velocity and wind direction, would need to be utilized to signal the threat of flooding. The effectiveness of an evacuation plan and response of the community to it cannot be accurately predetermined and consequently neither can potential flood damage reduction.

Flood Insurance (Alternative IID.2).

Flood insurance does little or nothing to prevent or reduce damages from flooding, but rather indemnifies the insured property owner against economic loss. Participation in the National Flood Insurance Program is a local option in which Mercer County is enrolled in the first or "emergency" phase and limited Federally subsidized coverage is available to all property owners. A Flood Insurance Study (F.I.S.) to convert from the emergency to the "regular" phase has not been scheduled for Mercer County as of August 1981. Auglaize County was identified by the Federal Emergency Management Agency as having flood-prone areas but to date the county has chosen not to participate in the program. Since this Federal program is available to the local governments, no further evaluation in this study is deemed necessary.

Flood Plain Management, Future Development

Zoning, subdivision regulations, and building codes for the lake shore flood plain could be accomplished on the basis of the flooded area. Ordinances could be developed that would allow only certain types of development in different flood zones. Developments such as parks, etc., which will not impede flow or be easily damaged may be permitted. Residential and commercial development could be permitted in areas subject to flooding, but not required for flowage provided that improvements were constructed or flood proofed to provide protection to the levels of protection specified by the public agencies involved. Although this approach will not improve the flood problem for existing construction, it will help to eliminate or greatly reduce the damages that would have otherwise occurred for future construction. This is particularly important in the study area in light of the potential for increased future development from implementation of centralized wastewater management alternatives. Regulations adopted by local governments either voluntarily or as required by participation in the Flood Insurance Program are considered to be one of the more practical non-structural measures that could be used to reduce future damages.

Lake Water Quality Improvement Alternatives

Lake water quality restoration measures considered but deemed inappropriate for various reasons are described as follows:

Destratification/Aeration (Alternative IIIB.2).

This is a restorative technique applicable to lakes in which the hypolimnion, (the bottom third layer in a stratified lake) is essentially devoid of oxygen. The objective is to artificially increase oxygen levels by mechanical means, thereby promoting the oxidation of organic substances and enhancing biotic distribution. The method is not a viable alternative for Grand Lake St. Marys since (1) oxygen levels in the lake are generally high from top to bottom, (2) the lake does not stratify because of its shallow depth, and (3) the technique would not restore the lake since it treats the symptoms rather than the source.

Nutrient Inactivation/Precipitation (Alternative III 3B.3).

This restorative technique is the physical addition to the lake of some type of chemical or inert material which absorbs or chemically bonds with soluble phosphorus and removes it from the water column. Chemicals such as aluminum sulfate are used to control nuisance algae and plant growth by settling nutrients to the bottom and making them unavailable to plants. Although relatively new as a lake restoration technique, it is essentially an extension of existing wastewater and water supply treatment technologies. The effectiveness of this in-lake treatment process is doubtful at Grand Lake St. Marys for several reasons: (1) the lake is well mixed throughout its depth and the chemical flocs formed would probably not settle to the bottom as would be required, but would remain in suspension and be shifted to lake shore areas; (2) addition of chemicals such as aluminum sulfate (alum) to lake water would impact adversely on existing water treatment; (3) tremendous amounts of materials would be required (1,500 tons every three years) at a cost of $232,000 per year, and (4) long-term impacts on fish and wildlife are unpredictable.

Dilution/Flushing (Alternative IIIB.4).

Another lake water quality improvement alternative investigated involves replacing the nutrient-rich lake water with nutrient-poor (higher quality) water from another source. The technique is used to prevent algae and plant growth by releasing excess nutrients from the lake. Several factors make this method impracticable for use at Grand Lake St. Marys. First, there is no adequate, dependable supply of dilution water in the region that can replace the lake contents. Second, groundwater is high in minerals, and would not be suitable unless treated prior to introduction to the lake. Thirdly, a low-nutrient water source is not available in proximity to the lake. Surface water supplies such as the St. Marys River and nearby Lake Loramie are undependable, expensive sources.

Drawdown (Alternative IIIB.5).

Drawdown is a technique used for water quality improvement in which the lake level is drawn down to expose and consolidate bottom sediments. It accomplishes several objectives including controlling rooted aquatic vegetation and stabilizing bottom sediments to prevent nutrient release from them. It also results in deepening the lake and increasing lake volume through sediment consolidation and/or removal after the drawdown. The method, however, has several drawbacks which make it unsuitable at Grand Lake St. Marys. It would be difficult to release water from the lake at a greater rate than inflow without causing some flooding downstream in Beaver Creek. There are inadequate outlet facilities to accomplish the drawdown over a short period of time. There would be a loss of recreation, and fish and wildlife resources. More importantly, there would be a significant reduction in now dependable water supply for Celina, severe aesthetic loss, and potentially offensive odors for an extended period of time.

Lake Bottom Sealing (Alternative IIIB.6).

It may be more feasible to prevent nutrient release from sediments by covering the sediments rather than by dredging or drawdown. Sealing, using such methods as covering sediments with polyethylene sheets, sand, clay or flyash, was examined but eliminated from further consideration since cost and material availability would prohibit its use on a lake of this size. In addition, not enough is known as to the permanance and stability of the treatment and the effects these sealants have on bottom living organisms and fish spawning areas.

Biotic Harvesting (Alternative IIIC.1).

Algae harvesting by mechanical means has been considered as an alternative for improving water quality, but is impractical at Grand Lake St. Marys because of the large lake surface area and widespread dispersal of algae blooms. Aquatic plant harvesting has also been discarded because of a lack of concentration of growth at the lake. The few aquatic plant areas that do exist should be preserved as habitat for bottom organisms, young-of-the-year fish, and wildlife. Harvesting of rough fish such as carp, which release nutrients by disturbing bottom sediment, has not been sufficiently studied to evaluate its impact on water quality and expected nutrient reductions.

ALTERNATIVES CONSIDERED IN DETAIL

This subsection discusses alternatives given active and more detailed consideration either because they have been suggested by local, regional and state interests, or because they would appear to have technical merit.

Flood Control

Structural plans considered for Beaver Creek and lake shore together, included detention basins, diversion and spillway/outlet modifications. In addition, non-structural reservoir regulation alternatives were examined. Structural plans considered for Beaver Creek alone included channel improvement alternatives (cleaning, clearing and snagging; and channel enlargement), and agricultural levees. Structural plans considered for lake shore alone included breakwaters, groins and shoreline levees.

Detention Basins on Tributaries (Alternative IA.1).

Detention basins refer to structures in which runoff from the lake's watershed would be stored in the basin during peak flood flows and released downstream to the lake as soon as conditions permit. The purpose is to reduce flood damage on the lake rim and store runoff that would otherwise be released through the lake to Beaver Creek. The ultimate objective is to prevent the lake level from rising more than one foot above west spillway crest. This elevation, 871.75, is the start of lake shore flood damage. With this plan, detention reservoirs would be constructed on four tributary streams, namely Coldwater, upper Beaver, Chickasaw, and Little Chickasaw Creeks, as shown on Plate 3. controlling areas of 9.3, 18.9, 15.3, and 6.6 square miles, respectively, for a total of 50.1 square miles or 45 percent of the total lake drainage area. Studies determined that those sites were not economically feasible to adequately reduce Beaver Creek and lake shore flooding and the costs of such a system would greatly exceed benefits. Total cost for constructing the four reservoirs was estimated at $14,800,000; average annual costs would total about $1,400,000. Considering that average annual equivalent damages are $235,000 for Beaver Creek and lake shore, this alternative would not be economically feasible. Adding recreation and sediment control benefits to the plan would still not result in a favorable project.

Diversion to Fourmile Creek (Alternative IA.2).

A plan consisting of diverting excess flow from the lake to another basin was also considered. The primary objectives were to reduce flood damages along Beaver Creek by allowing outflows from the lake in proportion to the historic drainage areas of the lake (59 percent Wabash River Basin, 41 percent St. Marys River Basin) and also prevent the lake level from rising more than one foot above the existing west spillway crest elevation which is the start of lake shore flood damages (elevation 871.75). This plan consisted of diverting lake overflows to the St. Marys River via Fourmile Creek as shown on Plate 4. The plan requires a new outlet structure and approximately 2 miles of deep-cut channel connecting the lake pool, through a portion of the State Park west of Villa Nova, to Fourmile Creek near U.S. Route 33. Total first cost of this plan is estimated at $3,500,000 and average annual costs total $299,000. Since total annual costs exceed potential annual flood damage reduction benefits for both Beaver Creek and lake shore ($235,000) the diversion plan was eliminated from further consideration.

Spillway/Outlet Modification (Alternative IIA.3).

This subject has been addressed in a report prepared in August 1979 for the Ohio Department of Public Works as previously discussed under "Status of Existing Plans and Improvements." The plan as proposed includes replacement of the existing east bank bulkhead with a new concrete ogee spillway having the same crest elevation as the present west spillway (870.75) and channel improvements providing greater flow capacity through the St. Marys Feeder Canal. According to the report the proposed modification provides for a west/east split of lake outflow equivalent to 59/41 percent which is the percentage of Grand Lake St. Marys drainage area tributary to the Wabash and St. Marys River Basins. The modification, according to the report, results in: (1) decreases in the outflows to Beaver Creek, (2) approximately the same maximum lake elevation, and (3) greater increases in east outflow to the St. Marys Feeder Canal.

The modification is expected to decrease outflows to Beaver Creek but of such low magnitude (on the order of 5 cfs and 15 cfs for 25-year, and 100 recurrences, respectively) as to result in negligible flood control impacts on Beaver Creek. In addition, because the expansive lake surface is capable of storing large volumes of inflow, the modified east spillway, though giving a large increase of east outflow, creates only a slight decrease in lake levels (on the order of 0.1 inch) thereby providing no measurable flood control impacts on the south shore.

Lake Regulation (Alternative IA.5).

Several plans for modifying the operation of Grand Lake St. Marys for flood control were investigated. The objective of this alternative is to reduce flood damages along the lake shore and Beaver Creek, as well as providing greater flexibility and dependability in obtaining and maintaining a stable seasonal recreational pool level.

A regulation schedule or plan of operation was apparently non-existent during the early years. However, after examining a 51-year record of pool elevations, it has been noted that there has been increasing emphasis on lake regulation during the last 15 to 20 years, with a corresponding emphasis for recreation and agricultural considerations. The existing "rule curve" includes a one-foot drawdown from recreation pool elevation 870.75 beginning the first of November. However, after the one-foot of flood storage is attained, minimal effort is exercised to maintain elevation 869.75 through the winter months. A practice of impounding some excess runoff early in the calendar year, to aid in attaining recreation pool by late March or early April, appears to prevail.

Alternatives considered in this study have included variations in (1) winter pool drawdown which would provide additional flood control storage, (2) initiation of pool filling to attain recreational pool requirements, and (3) controlled releases from the west spillway outlet to reduce flood damages along Beaver Creek and also south shore. Development, analysis and evaluation of hydrologic and hydraulic relationships of observed conditions for the period of record, existing operation schedule, and the variations of drawdown, filling, and releases revealed that the current operating procedures for lake regulation as followed by the State of Ohio provide an appropriate balance in minimizing flood damages for Beaver Creek and lake shore and maintaining a desirable recreation pool.

Clearing, Cleaning and Snagging (Alternative 1B.1.a.).

This channel improvement alternative consists of removal of flow-obstructing objects such as debris, logjams, shoals and bank vegetation for the purpose of restoring the channel to provide better hydraulic characteristics for Beaver Creek. Some excavation and reshaping would be required in addition to extensive replacement of tile outlets. Stump removal would not be included in order to preserve streambank stability and fish and wildlife habitat to the extent possible. This alternative, while being the least costly of channel improvements, was found to be the least effective in reducing flood flow heights and provides only short-term solutions since new growth and obstructions require that the operation be repeated at some later time. Total first cost of this alternative for 9.6 miles of channel improvement is $1,000,000. Average annual costs would total $97,000. Annual flood damage reduction benefits from the alternative would amount to $38,000. Since annual costs exceed annual benefits, this alternative is economically infeasible.

Channel Enlargement (Alternative IB.1.b).

This alternative was investigated for the purpose of increasing the Beaver Creek carrying capacity while lowering creek stages for better tile outlet discharge. The plan seeks to reduce agricultural flood damages. Two channel sizes were investigated. The smaller channel would have a bottom width of 40 feet at the upstream limit and 65 feet at the downstream limit. Total capital costs would be $1,610,000 and average annual costs would be $228,000. Annual flood damage reductions would be $70,800 making the alternative economically infeasible. The larger channel would have a bottom width of 60 feet at the upstream limit and 70 feet at the downstream limit. Total first cost is $5,342,000 and average annual costs would be $523,000. Average annual benefits of $77,100 are considerably lower than average annual costs making this alternative economically infeasible.

Agricultural Levees (Alternative IB.2)

Agricultural levees provide a possible means of reducing agricultural flood damages related to overbank flows. The plan examined consisted of 12.5 miles of levee, as shown on Plate 5, affording a 10-year level of protection for 1,148 acres along Beaver Creek. Total first costs are estimated at $4,000,000 with average annual costs of $308,000. Annual benefits attributed to the plan in the form of damages prevented amount to $60,700. Since average annual costs exceed average annual benefits, this alternative is economically infeasible.

Breakwaters (Alternative IIB.1).

The use of breakwaters at Grand Lake St. Marys was considered primarily as a measure to reduce shoreline flooding caused by wind set-up. Flooding of the shoreline due to wind set-up has been shown to be possible, particularly if the lake level is high. Breakwaters also have potential to reduce shore erosion by dampening wave impact forces and they can also improve water quality by reducing lake turbidity. For recreation, breakwaters could create stillwater areas for boating, thereby increasing boater safety, and providing access to deeper water for fishermen. Breakwaters also provide an obstruction to ice movement.

Of the many types of fixed and floating breakwater concepts available, two types in each category were selected as being applicable to the Grand Lake St. Marys wave situation. Fixed breakwaters examined include diked dredge islands, suitably contained, and rubblemound breakwaters since both represent the least expensive of fixed breakwaters, materials are available locally, and the shallow lake depth and wave situation are conducive to their use. Floating breakwaters examined include rigid floating concrete and flexible floating tire breakwaters, since the former has had application in similar wave environments and the latter has received considerable attention as an inexpensive alternative for reducing wave action in inland lakes.

It was found that to be effective for flood reduction, an extensive, complex and costly breakwater system would be required to realize significant reductions in wave action over the entire lake. Segmented, longitudinal fixed breakwaters (Plate 6, Figure 6A) oriented parallel to and close to shore have a greater potential for alleviating or reducing south shore flooding and erosion problems. Floating breakwaters would have little value for reduction of wind set-up at the shore but would assist in reducing wave-induced shoreline erosion.

Costs of breakwaters depend on several factors including location, orientation, and spacing in the lake. Order of magnitude costs have been developed based on a configuration which parallels the shore. It is estimated that costs to parallel the south shore with breakwaters would be $8,000,000 for dredge islands, $18,000,000 for rubblemound breakwaters, $12,000,000 for floating concrete breakwaters, and $2,000,000 for a floating tire system.

Based on the cost analysis conducted in this study, a single breakwater is not expected to produce enough of an effect on wave heights, shore erosion, or water quality to result in measurable direct or indirect monetary benefits. An extensive series of breakwaters would be required before benefits based solely on improvements to these problems could be realized. The most significant benefits to be realized would be for recreation with respect to boating and fishing in the form of income potential due to increased or restored lake visitation.

Groins

Groins are structures similar to rubblemound breakwaters, but connected to and somewhat perpendicular to land (Plate 6, Figure 6B). It was determined that because of the northerly exposure of the southshore, groins, connected to and in a northeasterly orientation to the southshore, may not be effective in alleviating the worst problem conditions resulting from wave action. They are not expected to achieve the desired impact of shoreline protection and from a benefit standpoint are not perceived to be economically feasible.

Shoreline Levees (Alternative IIB.2).

The concept of constructing shoreline levees for the purpose of protecting against flooding from high water levels, wind set-up and waves was also considered (Plate 6, Figure 6C). Two levee heights, 2 feet and 5 feet, were selected to provide protection from storms producing high water levels and winds up to 50 mph.

Two levee layouts were examined. The first retains total channel access by construction of the levee to follow the existing shoreline. The second minimizes levee length by cutting across boat access channels. Plate 7 shows a typical system conceptualized for the developed area west of Moorman Road.

There are many problems with this approach, the most notable of which are: aggravated upland drainage and ponding problems, disruption of privately owned waterfront property, reduction in access to open water and to boat docks, obstruction to lake view, and considerable rights-of-way across private property are necessary. Costs would be extremely high to protect all affected developed areas and are not cost effective for the expected level of reduced damages. Benefit to cost ratios for either of the approaches are less than 1.0 indicating that shoreline levees are infeasible.

Lake Water Quality Improvement Alternatives

Treatment of Wastewater Inflows (Alternative IIIA.1).

The deterioration of lake water quality is attributed, in part, to contamination by domestic wastewaters. A great portion of homes, resorts, and other public and private facilities surrounding the lake are not currently connected to public facilities and, therefore, use individual on-site systems (septic tanks) or small package treatment plants. Both methods have severe shortcomings when located near an impoundment because of improperly treated sewage seeping or discharging into the lake. Two disposal approaches were examined in dealing with wastewater inflows. The first involves elimination of all septic tank and package plants surrounding the lake and providing for collection, treatment and disposal of effluent directly to the lake. The method would require very high levels of treatment, at great expense, to remove excess nutrients prior to discharge to the lake. The second approach is to collect, divert, and treat domestic wastewater away from the perimeter of the lake such that no effluent would be allowed to discharge to the lake.

A regional sewage facilities plan for the developed immediate areas surrounding the lake has been prepared by Finkbeiner, Pettis & Stroud, Ltd. Wastewater would be collected and treated at plants in Celina at St. Marys with effluent discharged other than directly to the lake. Elimination of septic tank systems and numerous point source discharges through local management solutions utilizing the conventional collection and treatment alternative was seen as a positive step toward reducing pollutants to the lake and in particular bacteriological pollution emanating from human sources.

The contribution of nutrients from 20 domestic wastewater treatment plants that currently discharge directly or indirectly to the lake is minor, being approximately 2 percent of the total load entering the lake on an annual basis. This nutrient discharge will have a negligible impact on the long-range overall water quality of the lake with respect to phosphorus load and concentration. Likewise, phosphorus input to the lake from faulty septic tank-soil absorption systems close to the lake are contributing only small quantities of phosphorus to the lake (less than 2 percent). The implementation of a regional sewage system that encompasses the south shore is expected to reduce the existing phosphorus loading to Grand Lake by less than 10 percent and little improvement in the phosphorus concentration or trophic state of Grand Lake St. Marys would be anticipated as a result. (This may not be the critical concern, however, since the primary water quality improvement associated with the proposed sewage system is the reduction of bacterial pollution to the lake.)

Although the planned $14,000,000 regional sewerage project is seen to be a positive step toward reducing pollutants to the lake and in particular bacteriological pollution emanating from human sources and would effect a lifting on the currently imposed construction ban, a major unresolved question is whether centralized collection and treatment of wastewater, as planned, is justified because of the financial burden it places on its residents due to the high costs of collecting wastewater from each dwelling, especially along the south shore where houses are scattered.

Studies to re-evaluate regional sewerage needs to include modifying the scope of the existing plan; alternative and innovative on-lot systems, either on an individual household or group of households basis; and upgrading or converting existing treatment plants to include tertiary treatment and chlorination, are necessary but beyond the scope of this study. Federal funding is available to local governments through the Public Law 92–500, Section 201 Construction Grants Program to facilitate such studies.

Agricultural Source Controls (Alternative IIIA.2a)

Soil erosion, migration of phosphorus and other nutrients from cropland, barnyard runoff, and the application of manure on frozen ground are all problems in the Grand Lake watershed affecting water quality. To a large extent, the problems of eutrophication in the lake are the result of intensive agricultural land use within its watershed. Estimates are that 26,000 tons of sediment and 23 tons of total phosphorus reach the lake annually from agricultural areas. This phosphorus loading represents approximately 60 percent of the total annual load reaching the lake from all sources. From the standpoint of types of crops being grown, surface susceptibility to erosion is high, with 60 to 70 percent of the cropland area being planted in low density row crops, mainly corn and soybeans. In addition, farmers have been applying increasing amounts of phosphate fertilizer throughout northern Ohio. In Mercer and Auglaize Counties, there has been an approximate doubling of available phosphorus values for field crops between 1961 and

1976: from 30 pounds per acre to 51 pounds per acre in Mercer County and from 21 pounds per acre to 44 pounds per acre in Auglaize County. Reduction in phosphate yields to streams in the Grand Lake St. Marys watershed will, therefore, require controlling not only the loss of sediment from cultivated lands, but also the rate of fertilizer applications.

The use of agricultural land management has as its primary objective the abatement of soil and nutrient loss. From the standpoint of Grand Lake and its identified problems, the consequential benefits that can potentially be realized are (1) a reduction in sediment load, (2) a reduction in nutrient input, and (3) improved water quality. No significant adverse environmental impacts on the lake should occur as a result of improved agricultural practices.

A number of agricultural conservation practices are available for promoting and enhancing long-term productivity of the soil. Although few of these practices were originally developed to improve water quality, these practices are now recognized as being beneficial to water quality and soil protection as reflected in new cost-sharing programs. Conservation practices available through cost-sharing programs include: conservation tillage; establishing hay or rotation pasture; improving permanent hay or grass stands; stripcropping, terraces; diversions; winter crop cover; shaping and seeding critical soil loss areas; sediment retention, erosion or water control structures; stream protection and soil waterways. In general, the following cultivation techniques appear most suitable for the Grand Lake St. Marys watershed: delayed plowing and residue management, cover or green manure crops, minimum tillage, and no-till planting.

The purpose of the cost-sharing programs is to encourage landowners to install conservation practices to protect and preserve the land for future use. The proper use of the practices and costs involved are dependent upon detailed conservation planning for individual farm units, taking into account the needs and objectives of the individual landowner, and are beyond the scope of this study. Likewise, total benefits and costs to be realized in the Grand Lake St. Marys watershed by the implementation of various agricultural waste management and conservation techniques cannot be specified. However, both Mercer and Auglaize Counties rank high as preferred areas for agricultural management practices.

Potential benefits to individual landowners include increased crop yields, long-term reduction in topsoil and nutrient losses, decreased fertilizer requirements, and potential reductions in labor if fewer operations are involved.

In general, costs to individual landowners would exceed these benefits, but Federal and/or State cost-sharing could shift the balance to favor implementation and reduce the economic burden. Indirect monetary benefits to "downstream" users would be difficult to ascertain, but would include increased lake usage due to water quality improvements.

If all cropland in the watershed could be managed to satisfy Soil Conservation Service-designated maximum allowable erosion rates (T–factors), the following estimates of improvement could be realized:

- Gross erosion could be reduced from the current 4.28 tons per acre per year to 2.05 tons per acre per year, a 52 percent reduction

- The annual sediment load to Grand Lake could be reduced from 0.428 tons per acre to 0.205 tons per acre, a 52 percent reduction

- The annual phosphorus load to Grand Lake could be reduced by 9.6 tons, or 40 percent of the estimated total phosphorus load to the lake.

- Long-term water quality improvement.

- Increase in productivity and crop yield for some agricultural land management alternatives.

Livestock Waste Management (Alternative IIIA.2b)

Potential pollution of water courses as a result of livestock operations is particularly critical in the Grand Lake St. Marys watershed due to the widespread presence of animal feedlots. Animal concentration areas are a problem when rainfall runoff carries manure with high concentrations of suspended solids, nutrients, bacteria, and oxygen-demanding materials into surface water.

There are approximately 12,000 animal units producing 236 tons of total phosphorus per year in the lake's watershed. A conservative estimate is that 5 percent of produced phosphorus will be exported to a watercourse if livestock operations are located within 3,000 feet of a receiving stream. Approximately seventy (70) percent of the livestock are so located. Therefore, the annual phosphorus load to Grand Lake as a result of livestock operations is estimated to be 8.3 tons. If discharges from livestock operations can be completely eliminated, a 35 percent reduction in the annual nutrient input to the lake can be realized and result in reduced phosphorus concentrations in the lake.

Proposed State of Ohio Regulations call for zero pollutant discharge from some pollutant sources and minimizing pollution potential for all "concentrated animal feeding operations." Most of the livestock operations in the Grand Lake St. Marys watershed will be subject to the regulations.

The State of Ohio has developed a Livestock Waste Management Guide which helps the livestock operator to make decisions in choosing and operating a livestock waste handling system which controls pollution. In addition, primary benefits to the livestock operator are increased value of manure for crop production, an increase in feed efficiency, and potentially reduced labor requirements. Typical capital investment costs for dairy cows, beef cattle, and swine (the predominant watershed livestock types) are $200 per head, $100 per head, and $20 per head, respectively. Typical annual operating costs per head are: dairy cows, $50; beef cattle, $25; and swine, $5.00. In general, costs to the individual owner/operator exceed benefits. Cost sharing could shift the balance and encourage implementation. Indirect benefits would be to downstream water users, including increased lake usage due to improvement in lake water quality.

Treatment of Tributary Inflows (Alternative IIIA.2c)

This is a method of treating tributary flow with chemical flocculents with the objective to remove phosphorus and suspended sediment by settling them out prior to inflow to the lake. Facilities would be required on each of the five major tributaries to the lake. Several problems exist with this approach, however. Chemical treatment is limited by the extreme fluctuations in flow rate and the need to vary the chemical rate. While actual chemical addition has a relatively low cost due to low phosphorus concentrations, the process produces sludge that would cause environmental and water quality concerns and facilities for its removal would be cost prohibitive. Treatment facilities would be required capable of treating 43 million gallons per day which is, by comparison, twelve times the design flow rate for the Celina Sewage Treatment Plant, and is therefore physically and economically infeasible by a wide margin.

Other Non-Point Source Controls

Precipitation Phosphorus Control

Precipitation contributes an estimated 780 kilograms of phosphorus or 2.3 percent of the annual total to Grand Lake St. Marys. This phosphorus originates principally outside the lake basin from such sources as wind-induced soil erosion, industrial ash, smoke, certain mining activities, and the addition of organic phosphates to gasoline. It takes the form of particulate phosphorus carried by wind and other input processes which is later removed by rainfall and other precipitation. In general, it can be said that the phosphorus content of direct precipitation on the lake surface, besides being small as compared to other sources, is not manageable or controllable by man. In addition, the availability of phosphorus in rainfall to algae is still in question with researchers.

Goose Population Control

Less than one percent of the total annual phosphorus load to the lake is attributed to waterfowl (primarily geese), but the amount available to the lake system is considered insignificant. Therefore, any program recommending a reduction in waterfowl population on Grand Lake by hazing or hunting is expected to have little impact on lake water quality.

Urban and Suburban Runoff Control

Direct urban and suburban runoff in areas directly adjacent to the lake contributes approximately 3 percent of the total phosphorus load to the lake. In addition, fertilizers, pesticides, detergents, oil, grease, salts, domestic animal wastes, and street litter are carried through ditches directly to the lake. Property owners can have a positive effect on water quality by reducing the amount of pollutants in stormwater runoff to the lake. This can be accomplished by minimizing fertilizer and pesticide applications, composting yard debris, frequent street cleaning, and using low phosphate detergents.

Dredging (Alternative IIIB.1).

A widespread dredging of Grand Lake St. Marys has been considered since in-lake dredging addresses more planning objectives than any other alternative. In addition to deepening the lake for the benefit of recreation uses, dredging is a potential lake restoration technique for improving water quality by removing the accumulated products of degradation (phosphorus-enriched sediment) from the lake system. It has been determined that Grand Lake St. Marys contains high concentrations of sediment-bound phosphorus. In shallow lakes such as Grand Lake St. Marys, nutrient release from the sediments by wind-generated mixing, boat motors, and bottom scavengers can be a major source of excessive nutrients. Thus, dredging to expose a nutrient-poor layer can, in theory, result in nutrient concentration reductions in the water column. Potential secondary considerations from dredging include decreasing wind-generated wave action and lake shore erosion, improving lake level fluctuations, and improving water-related recreation.

With regard to water quality, the results of modeling the lake system under various scenarios and conditions of external load reductions, sediment mixing (with and without), spoil disposal (in-lake and out-of-lake), and dredging (no dredging, 3 feet of dredging), have indicated that no significant improvements in the phosphorus concentration and related biologically-oriented nuisance condition (proliferation of algae) can be expected from the dredging of bottom sediments at Grand Lake St. Marys. In fact, some degradation of water quality could result if the dredged spoil material is contained within the lake. In-lake disposal appears to be the only practical method since the flat topography and lack of suitable sites inhibit disposal on the watershed. The primary reason for a negative impact on water quality is that any projected wide-scale dredging operation would either remove an insignificant depth of sediment over the entire lake, thereby exposing more of the same phosphorus-laden sediment, or as removing all the accumulated sediment from an inconsequential portion of the lake as is now being done. The analysis of the movement of sediment in the lake due to wind and resultant bottom transport have shown that no significant reduction of suspended sediments can be expected, even for the extreme case of 3 feet of sediment removal, and, therefore, no noticeable improvement in water quality can be expected as a result of the alleviation of wind-mixing effects by dredging.

With regard to physical improvements due to dredging, flooding of downwind shorelines due to long period set-up of the water surface could be reduced by a wide-scale dredging program, but in conflict with this, results indicate that the existing severe wave action is expected to be aggravated further by extensive dredging of the lake bottom. A similar conclusion is reached regarding erosion of the lake shoreline. Even though wind set-up impacts on the erosive process, a greater concern is intense wave action and the overtopping of erosion control structures. Lake bottom dredging intensifies short-period waves and would be detrimental to shoreline erosion.

Long-term fluctuation in lake levels will not be significantly influenced by dredging. If anything, the situation would be aggravated if dredge spoil is contained within the lake because as the surface area is reduced, the change in water level resulting from a unit increase or decrease in water volume is greater.

The major benefits of a wide-scale dredging program at the lake are associated with water-based recreation. These would include increased boater access to extended portions of the lake, improved boater safety by elimination of shallow (and stumped) areas, enhancement of fish habitat and related recreational fishing in the long-term. Additionally, dredging has the potential for extending wildlife areas by the creation of dredge islands or other new landforms from dredge spoil materials.

The two major constraints to dredging are (1) proper containment and disposal of huge volumes of dredged materials and (2) economic feasibility.

As mentioned earlier, in-lake disposal appears to be the only practical method since the flat topography and lack of suitable sites inhibit disposal on the watershed. A large-scale, lake-wide dredging program, however, may be cost prohibitive. Costs and volumes for comparison are given as follows:

Average Lake Depth, Feet	Cost to Achieve Average Lake Depth	Dredged Material Volume Million Cubic Yards
4	$13,200,000	6.6
6	37,200,000	18.6
8	88,600,000	44.3

An estimated $135,000,000 would be required to remove an average of 3 feet of sediment throughout the lake to achieve an 11-foot average lake depth.

Dredging would have negligible direct monetary impact on nuisance south shore flooding, erosion, and wave attenuation; however, improvements in water-based recreation as a result of a wide-scale dredging program would provide indirect monetary benefits from increased lake usage. A direct benefit of a dredging program would be increased revenue generated from the sale of dredge islands, peninsulas, or other newly created land forms to offset the cost of dredging.

Erosion and Sedimentation Control Alternatives

Erosion control alternatives were investigated for unprotected shoreline, streambanks, and upland areas of the lake watershed.

Shoreline Erosion Protection

In addition to breakwaters previously discussed, other alternatives to eliminate or reduce shoreland erosion are the traditional uses of riprap, gabions, bulkheads (Plate 8, Figures 8A, 8B, 8C) or concrete fabriform mats. Each of these structural measures has the beneficial effect of reducing erosion, protecting against loss of shoreland, and reduction in sediment load to the lake. Of these methods, bulkheads and concrete mats would impair drainage behind them. All methods would contribute somewhat to reductions in access to open water and boat docks, require land to establish desired slope at the shore and cause localized disruption during construction.

In general, shoreline erosion problems are limited to the southshore where bank erosion occurs along the undeveloped shore reaches. Some attempt has been made to riprap these publicly-owned areas, but the success of any program is limited by access problems.

Complete protection of 60,000 feet of currently unprotected, irregular southshore areas would cost $1.62 million for riprap, $2.5 million for gabions, $3.6 million for bulkheads, and $3.74 million for concrete mats. Use of these measures, however, are more cost effective than near shore breakwaters. Treatment of privately-owned shoreline is the responsibility of the owner. Unprotected public shoreline is the responsibility of the State of Ohio.

Streambanks

Tributary streambanks have the lowest protected length among the four categories (streambank, channels, lake shore, and islands) at Grand Lake and therefore, appear the most susceptible to the disposal of erodible material to the lake. Retardation of streambank erosion would be beneficial in stabilizing land bordering the tributary and reducing sediment load to the lake. While the dominant sediment load is watershed soil loss, streambank erosion could increase in the future with progressive development and urbanization of the watershed. This is of particular concern on Coldwater Creek due to the high current and projected rates of development around the municipality of Coldwater. The range of typical costs to completely protect accessible portions of seven tributaries are estimated as follows:

	Feet	(Least Cost) Riprap	(Greatest Cost) Concrete Mats
Coldwater Creek	18,000	$486,000	$1,120,000
Chickasaw Creek	15,000	405,000	936,000
Little Chickasaw Creek	6,000	162,000	374,000
Prairie Creek	9,000	243,000	936,000
Barnes Creek	6,000	162,000	374,000
Monroe Creek	4,000	108,000	250,000

Coldwater Creek should be given priority streambank protection due to high potential for upstream development which will increase peak flow rates and promote erosion of banks.

Watershed Soil Erosion

Conservation practices available through government cost sharing programs include among others: establishing hay or rotation pasture, improving permanent hay or grass stands; strip cropping; terraces; minimum or no tillage practices; winter crop cover; sediment retention structures; erosion control structures; stream protection; sod waterways; grass buffer strips between crops and waterways. The purpose of these conservation measures is to protect and preserve the land for future use and would be effective in controlling sediment and nutrients from entering the streams which drain to the lake. The proper use of the practices and costs involved are dependent upon detailed conservation planning for individual farm units, taking into account the needs and objectives of the individual land owner. Locations where priorities should be given to specific agricultural practices are the Coldwater Creek, Beaver Creek, and Chickasaw Creek watersheds.

Sedimentation Ponds

These physical structures have been considered to reduce the amount of sediment and nutrients entering the lake. The purpose of the ponds is to provide a containment area in which flowing water is slowed long enough to settle large amounts of suspended and settleable particulate matter during runoff events thereby reducing the sediment load to downstream water bodies and providing for easier removal of the collected matter. In addition, sediment ponds would remove nutrients attached to the captured sediments. The long-term effect of these ponds is improvement of the lake's water quality. Adverse impacts of sedimentation ponds are the creation of localized nuisance conditions (weeds), threat of possible washout, need for currently productive land, long-term commitment to operation and maintenance for periodic cleanout and disposal of sediment.

Depending on the design retention time required, estimated total cost of seven sedimentation basins (one each of the major tributaries to the lake) is on the order of $1,280,000 for 4-hour retention and $6,220,000 for 20-hour retention.

DISCUSSION

The purpose of this section is to discuss the more pertinent findings in the related problem categories examined in the Grand Lake St. Marys survey investigation.

FLOODING, BEAVER CREEK

1. Periodic flooding of agricultural land along Beaver Creek is attributed, in part, to a limited flood control capability of Grand Lake St. Marys, poor surface drainage, low stream gradient, inadequate outlet for numerous artificial agricultural drains, and constrictions to flow from vegetation on the banks, shoals, and debris throughout 9.6 miles of the 10.6-mile reach.

2. Flooding problems along Beaver Creek are due to both overbank inundation and subsurface saturation as a consequence of long periods of near bankfull flow in the flat gradient channel.

3. Peak discharges from the Grand Lake St. Marys western outlet are not great enough to cause instantaneous flooding, and are less than would be experienced without the lake. The lake does provide some limited flood control, but extends the period of bankfull flow in Beaver Creek. Current regulation practices for the Grand Lake St. Marys western outlet will reduce natural peak discharges from excessive runoff to a modified condition. Lake outflows are maintained, when structurally possible, to reduce natural Beaver Creek flows to a maximum bankfull flow. Lake storage capacity is estimated to be 1-3/4 inches of runoff (based on total contributing drainage area including the lake) from elevation 869.92 to elevation 870.75 (west spillway crest). Additionally, from elevation 870.75 to one foot above west spillway crest an estimated 2-1/4 inches of runoff storage is available. To deplete stored waters at a net outflow rate of 150 cfs will require approximately 35 days

and 46 days for the 1-3/4 inche and 2-1/4 inches of runoff, respectively. Therefore, the flood control capability of Grand Lake is considered limited.

4. Flood damages to crop, non-crop, transportation facilities, and public utilities in the Beaver Creek reach from its confluence with the Wabash River upstream to the western outlet of Grand Lake St. Marys is estimated at $85,000 annually. Of this total, approximately 74 percent is damage to major crops produced – corn, soybeans, and hay.

5. Non-structural flood protection measures considered that would modify damage susceptibility, such as weather modification, pre-flood emergency action, flood proofing, evacuation, flood plain zoning, land use regulation, flood forecasting and flood insurance, are not viable solutions because of the agricultural character of the Beaver Creek flood plain.

6. Structural plans considered for Beaver Creek, including detention basins, diversion to another basin, clearing and cleaning, channel improvement and agricultural levees, were all found not to be cost effective means for reducing flood damages along Beaver Creek. This finding is based on Federal cost analysis procedures which tend to reflect higher costs than would locally sponsored projects.

7. The Ohio Public Works proposal to release a greater proportion of lake peak inflows to the St. Marys River Basin through modification of the eastern embankment outlet works and channel is expected to decrease outflows to Beaver Creek, but of such low magnitude as to result in negligible flood control impacts on Beaver Creek.

FLOODING, SOUTH SHORE

1. Periodic flooding occurs along the south shore of Grand Lake St. Marys where the topography and developments are generally at a low elevation. The flooding is attributed to many factors including poor natural drainage plus a high water table, and to a high lake level combined with wind-induced wave action which causes water to run up on the shore with subsequent damage to residential buildings and contents. In most years, the

lake level does not exceed one foot above west spillway crest, but this rise is sufficient to cause flood damages on the south shore.

2. Present annual damages to residences in the form of structure and contents damage are estimated to be $150,000 for approximately 142 private shoreline properties.

3. Non-structural measures such as permanent or temporary evacuation, relocation, flood plain zoning, subdivision regulation, and building codes were considered alternatives to existing impacted properties, but were eliminated from further consideration because these flood plain measures have negligible effects on reducing flood damages to structures currently in the flood plain.

4. Flood proofing, involving waterproofing or raising structures to prevent flood water intrusion, is inhibited by the predominance of single-family frame structures on individual lots and is not cost effective as a primary solution to reducing or eliminating south shore flood damages.

5. The considered structural alternatives such as detention basins, diversion, and shoreline levees are not cost effective methods of preventing or alleviating south shore flood damages.

6. Several plans were examined for modifying the operation of Grand Lake St. Marys in order to reduce flood damages along the lake's south shore and Beaver Creek, as well as for providing greater dependability in obtaining and maintaining the seasonal recreational pool level. It was found that the current operating procedures for lake regulation, consisting of maintaining a lake level about 10 inches below the west spillway crest during the winter months and closing the gates on 15 March for refilling provide an appropriate balance in minimizing flood damages and maintaining a desirable recreation pool.

7. Periodic flooding of the shoreline due to wind setup has been shown to be possible, particularly if the lake water level in Grand Lake is high. Therefore, relief, under these conditions, could be provided by strategic placement of fixed breakwaters such as dredge islands or rubblemound breakwaters. Floating breakwaters would have no effect on wind setup.

8. A fixed breakwater system that spans the length of the south e is perceived to be an appropriate technical solution for alleviating both south shore erosion and flooding problems due to wave action, but an extensive series of breakwaters about 40,000 feet long and close to shore would be required before benefits based solely on improvements to these two problems could be realized.

9. Fixed breakwaters are not perceived to be economically feasible solely from a flood damage reduction benefit standpoint, but from a recreational usage, water quality and physical improvement standpoint, an expenditure for construction of a properly designed breakwater system would be preferred to the dredging that could be done for the same amount.

10. A fixed breakwater system parallel to the south shore could prove more beneficial for shoreline erosion and flooding problems due to wave action than a groin system placed somewhat perpendicular and connected to the south shore.

11. The Ohio Public Works proposal to release a greater proportion of lake peak inflows to the St. Marys River Basin through modification of the eastern embankment outlet works and channel is expected to create only a slight decrease in lake levels (on the order of 0.1 inch), thereby providing no measurable flood control impacts on the lake south shore.

LAKE WATER QUALITY

1. Lake water quality has been declining in recent years. Four separate water quality problems have been identified as causing the deterioration. Bacterial contamination from human sources threatens body contact recreation, particularly in areas of greatest development. High nutrient concentrations result in severe blooms of algae which cause taste and odor problems. Water clarity is reduced by algae and suspended sediment, resulting in unattractive conditions for recreators. Accumulation of sediment, eroded from upland areas, and unprotected shoreline has reduced the lake depth.

2. The lake's ambient total phosphorus concentration of 178 micrograms per liter (ug/l) remains well above 15 ug/l, the generally accepted threshold level for algal blooms in northern lakes. Continuing nuisance growth of algae in the lake indicates that the problem of cultural eutrophication needs to be resolved.

3. The present phosphorus loading rate of 0.49 gram per square meter of lake surface per year is nearly 1.8 times the rate commonly considered as a dangerous eutrophic rate indicating that phosphorus inputs should be reduced or minimized to slow the cultural aging of the lake.

4. Approximately 33,000 kilograms of total phosphorus are currently contributed to the lake on an annual basis from all sources. Of this total approximately 45 percent is removed from the lake annually via Beaver Creek, the St. Marys feeder canal, direct fish harvest, and absorption into lake sediments. At current estimated rates of phosphorus input and output, approximately 18,000 kilograms of total phosphorus accumulate annually in the lake.

5. Total annual phosphorus loadings to Grand Lake St. Marys from specific sources are estimated as follows:

	Total Phosphorus		Percent
	Pounds	Kilograms	of Total
Precipitation	1,720	780	2.3
Waterfowl (geese)	475	216	.6
Animal Concentration Areas (feedlots)	16,540	7,500	22.6
Agricultural Runoff	46,305	21,000	62.9
Municipal Point Source (St. Henry)	3,195	1,449	4.3
Domestic Point Sources	1,646	746	2.2
Septic Tanks	1,345	610	1.8
Direct Urban and Suburban Runoff	2,394	1,088	3.3
Total	73,620	33,389	100.0

6. Several sources of phosphorus input which were previously thought to be significant, specifically septic tank systems and waterfowl, are contributing only small quantities of phosphorus to the lake.

7. The most significant contribution of phosphorus to the lake appears to be from non-point sources or rural, primarily agricultural land and livestock concentration areas. These areas contribute an estimated 86 percent of the total annual phosphorus load to the lake.

EROSION AND SEDIMENTATION

1. The shoreline in several areas around the lake, particularly State-owned lands along the south shore, is undergoing moderate erosion and needs stabilization. Until lake banks are stabilized and lake fluctuations are controlled, turbidity levels in the lake, due in part to shoreline erosion, will continue to remain high.

2. Erosion of unprotected shoreline areas contributes to the turbidity level of the lake but only when heavy wave action is present. At these times turbidity levels are raised considerably in the immediate area of the erosion, but it is doubtful that the complete stabilization of the lake's shoreline would reduce the turbidity and sedimentation of the lake by any appreciable degree. The major cause of turbidity and sedimentation at Grand Lake is the introduction and subsequent resuspension of sediment from thousands of acres of eroding farm land located in the drainage basin above the lake.

3. The rate of streambank erosion is currently not excessive even though the streambanks of the tributaries to Grand Lake have the lowest percentage of protected length among the four categories of streambank, shoreline, island, and dredge spoil. However, streambank protection can become important in the future and streambank erosion rates could be significantly increased as progressive development and urbanization cause increases in peak discharge rates in the tributaries.

4. Streambank erosion is of particular concern in Coldwater Creek (due to the high current and projected rates of development around the municipality of Coldwater) where noticeable widening of downstream reaches has already occurred.

5. To a large extent, the problems of sedimentation and water quality problems (eutrophication) in the lake are the result of intensive agricultural land use within its watershed. It is estimated that 26,000 tons of sediment and 23 tons of total phosphorus reach the lake annually from agricultural areas. From the standpoint of types of crops being grown, surface susceptibility to erosion is high, with 60 to 70 percent of the cropland area being planted in low density row crops, mainly corn and soybeans.

6. Erosion and sediment loads from boat access channels around Grand Lake St. Marys are not a severe problem since these channels are not subjected to the erosive forces of streamflow and waves, and a large percentage of boat channel lengths has already been protected from boat wake attack. The potential effects of channel erosion are better handled by individual property owners using protection measures similar to streambank protection.

7. Existing islands, although especially susceptible to ice and wind-induced wave erosion because of their small size and exposure from any side, contribute minimally to both the annual sediment load to the lake and the overall recreational usage of the lake. What is in question, however, is the preservation of these islands for their intended long-term use as waterfowl areas.

8. In the case of existing islands, alternatives for preventing continued erosion include retrofitting shore protection measures, allowing the natural loss of the islands to proceed, or developing a large scale plan related to creation of large dredged material containment areas that could include the existing islands within protected dikes.

9. Grand Lake St. Marys is currently a eutrophic water body and can be expected to remain as such until an approximate 60 percent reduction in the annual phosphorus load is realized. This percent reduction is quoted with reservation since the high degree of wind-induced resuspension of nutrient-rich bottom sediments limits the use of generally accepted trophic state criteria.

10. Lake water quality will not be improved by dredging of bottom sediments. In fact, some degradation of water quality could result if the spoil materi-' is contained within the lake. Water quality problems and physical problems would not be significantly impacted by an extensive lake-wide dredging program. The extent of dredging required for large-scale recreation improvement is cost prohibitive.

11. Reducing the nutrient load to the lake is the most effective measure for improving lake water quality. Because of a lack of permanent phosphorus loss to the sediments, and because phosphorus does not appear to be readily available for release into the lake due to the aerobic nature of the lake water, the reduction in the steady-state concentration of total phosphorus in the lake water is proportional to the reduction in the loading rate.

12. Within three years of a reduction in nutrient loads, the total phosphorus concentration in Grand Lake is expected to reach approximately 90 percent of its new steady-state value.

13. The contribution of nutrients from 20 package domestic wastewater treatment plants that discharge directly or indirectly to the lake is minor, being less than 2.5 percent of the total load. The discharge of the treated sewage from these plants will have a negligible impact on the long-range overall water quality of the lake as far as phosphorus load and concentration is concerned. The major concern with these point discharges, according to recent studies (August 1980 by Finkbeiner, Pettis and Strout, Ltd.) is related to high bacteriological concentration which at peak week-end periods of use affect the entire lake. Likewise, potential phosphorus migration from 500 permanent and 169 seasonal septic tank-soil absorption systems is estimated at less than 2 percent of the total phosphorus loading to the lake and is, therefore, considered to be a minor contribution.

14. The implementation of a regional sewage system along the south shore is expected to reduce the existing phosphorus loading to Grand Lake from septic tank systems and domestic point sources by less than 10 percent. Little improvement in the phosphorus concentration or trophic state of Grand Lake would be anticipated as a result of elimination of this source alone. This is not the critical concern, however, since the primary water quality improvement associated with the sewage system is the public health-related reduction in bacterial pollution to the lake.

15. A major unresolved question is whether collection and centralized treatment of wastewater generated along the lake shore, as has been proposed by ongoing Section 201 planning, is feasible because of the financial burden it places on its residents due to the high cost of collecting wastewater from each dwelling, especially where houses are scattered.

16. If all cropland in the watershed could be managed to satisfy Soil Conservation Service designated maximum allowable erosion rates (T–factors), the following estimates of improvements could be realized:

- Gross erosion rates could be reduced from the current 4.28 tons per year to 2.05 tons per acre per year, a 52 percent reduction.

- The annual phosphorus load to Grand Lake could be reduced by 9.6 tons, or 40 percent of the estimated total phosphorus load to the lake.

- Long-term water quality improvement.

- An increase in productivity and crop yield for some agricultural land management alternatives.

17. Agricultural management practices are technically feasible, but results would vary with the practice and individual sites to be treated.

18. Both Mercer and Auglaize Counties rank high as preferred areas for agricultural management practices.

19. The annual phosphorus load to Grand Lake as the result of livestock operations is estimated to be 7,500 kilograms.

20. If discharge from livestock operations can be completely eliminated, a nearly 25 percent reduction in the total annual nutrient input to the lake can be realized and result in reduced phosphorus concentrations in the lake.

21. A mechanism exists, through State of Ohio Regulations, for zero pollutant discharge from some pollutant sources and minimizing pollution potential for all "concentrated animal feeding operations;" however, in general, costs to the individual owner/ operator exceed benefits. Public cost sharing is available to assist in offsetting costs because some benefits are to the general public.

22. Treating tributary inflows, directly, with the objective to remove phosphorus and suspended sediment is cost prohibitive.

23. According to estimates in this investigation, less than one percent of the total phosphorus load is attributed to migrating and nesting geese and the amount available to the biological system is judged to be insignificant. Any program recommending a reduction in goose population on Grand Lake St. Marys would have little impact on water quality.

24. Urban and suburban runoff in the Grand Lake St. Marys watershed originates from the Village of Coldwater, portions of Celina adjacent to the lake, and developed direct drainage areas surrounding the lake. The phosphorus loading from these areas makes up an estimated three percent of the total phosphorus loading to the lake.

CONCLUSIONS

The following conclusions have been reached as a result of the Corps of Engineers investigation at Grand Lake St. Marys. The conclusions and subsequent recommendations reflect Corps of Engineers judgments regarding desirable future actions and priorities, not necessarily limited by existing feasibility or authorizations.

BEAVER CREEK FLOODING

Channel clearing and cleaning is the most cost effective measure for reduction of flood damages along Beaver Creek.

LAKE SHORE FLOODING

Nonstructural measures such as raising structures in–place and temporary evacuation in combination with a flood warning system may best reduce structural flooding problems as exist along the south shore.

Shoreline erosion and property damage can effectively be reduced by measures such as rubblemound breakwaters. Consideration should be given to a demonstration project utilizing a partial fixed breakwater system or islands along an affected south shore area.

WASTEWATER TREATMENT

Continued efforts should be directed toward reducing bacterial contamination and phosphorus loading introduced to the lake from sewage wastes. This can be accomplished by regional collection, treatment and disposal outside the lake watershed or by improved on–lot and "package" plant alternatives or a combination of solutions. Because of the relatively high cost of installation of a centralized sewerage system, the Ohio Water Development Authority has received a grant from the U. S. Environmental Protection Agency to perform additional facility planning and consider alternatives to the proposed centralized system. From the point of view of best lake water quality management, discharge of all sewage effluent to some point outside the lake watershed would be the preferred alternative.

SEDIMENT REDUCTION

Shoreline protection utilizing a combination of protective measures (riprap placed over a thickness of filter material) and no action (allowing the shore to assume a natural angle of repose) offers the best opportunities with priority areas as follows:

1. Portions of Montezuma Bay
2. North exposure reaches of the Mercer County Waterfowl Refuge shore
3. West of Prairie Creek
4. West of Moorman Road
5. West of Behm Road (Duckfoot's Landing)
6. East and west of mouth of Chickasaw Creek
7. Area between South Shore Acres and Channel Isle
8. West of Barnes Creek
9. East embankment recreation area.

Streambank protection should be utilized where erosion is occurring through such measures as streambank fencing, grading and seeding of banks, or rearranging pasture and cropland with priorities in Coldwater Creek and Chickasaw Creek.

Erosion and sediment control practices, in accord with Soil Conservation Service and Ohio Department of Natural Resources standards and specifications, should be utilized at all construction sites.

In-Lake disposal of dredged material appears to be the most practical method of disposal. Riprap should be placed along shoreline facing the lake with additional consideration given to one or two large islands constructed to serve as breakwaters and then several small islands constructed behind them (riprap shoreline of large islands only).

SEDIMENT CONTROL AND PHOSPHORUS REDUCTION

Management methods for runoff control should be employed in the following areas:

1. Efficient fertilizer and pesticide application – lakeshore residents; areas adjacent to the lake including cropland areas.

2. Composting yard debris – lakeshore residents; areas adjacent to drainageways to the lake.

3. Frequent street sweeping – developed areas adjacent to the lake (Celina, Montezuma, north and south shore); Coldwater.

4. Use of low phosphate detergents – north shore from Harbor Point to Lakeland Beach, Northwood and Sandy Beach; southshore from Village of Montezuma to Southmoor Shores.

5. Reduce sediment and phosphorus loads from agricultural areas by "best management practices" implemented under traditional soil conservation programs.

6. Bring all agricultural land under Soil Conservation Service criteria for allowable soil loss.

7. Investigate measures to increase funding levels of current conservation programs.

8. Consider legislation at the State level to enforce standards to reduce soil loss.

9. Conservation practices should be promoted in the lake watershed through State and Agricultural Stabilization and Conservation Service cost-sharing programs.

10. A detailed inventory of the potential sediment, phosphorus, and animal waste pollution problem areas should be conducted in the lake watershed to more accurately determine the extent of the problem.

11. The practice of conservation tillage and ultimately no–tillage should be encouraged in the lake watershed on properly drained soils.

12. Animals should be housed on or above an impervious base. In no case should runoff from livestock areas be allowed to discharge directly to waterways of the watershed. Methods such as frequent waste removal and storage, direct application to land, manure storage facilities, interceptor trenches, holding ponds and fenced waterways should be encouraged.

13. Priority areas for livestock waste management practices are those within 3,000 feet of waterways where an estimated 70 percent of animal concentration areas are located.

14. Grass buffer strips between row crops and waterways should be encouraged in areas adjacent to Prairie, Coldwater, Chickasaw, Barnes and upper Beaver Creeks.

15. Existing wetlands should be preserved to aid in filtering out nutrients and sediments; priority areas are Chickasaw, Prairie and Barnes Creeks, and small wetlands adjacent to animal concentration areas or critical soil/nutrient areas.

16. Close cooperation is considered necessary between the U.S. Fish and Wildlife Service, the Ohio Department of Natural Resources, and the Corps of Engineers in determining and evaluating suitable dredge spoil sites and project design.

17. The Dredging Operations Technical Support (DOTS) team, an activity of the Environmental Laboratory of the Waterways Experiment Station, U.S. Army Corps of Engineers, Vicksburg, Mississippi, should be consulted as a possible means of assisting the State in preparing a long–range dredging plan for the lake.

18. In-lake dredging should be limited to selective dredging of nearshore zones for lake access, boater safety improvements, and public lands development.

19. The conclusions reached with regard to sediment control and phosphorus reduction provide the basis for consideration of a Section 314 Clean Lakes project.

RECOMMENDATIONS

Based on the conclusions contained in this report and following coordination with pertinent Federal, State and local interests, whose comments and responses generally concur in the study conclusions, no further action by the Corps of Engineers is found feasible at this time in providing improvements in the interest of flooding, water quality, and other water and related resources at Grand Lake St. Marys, Ohio. However, an improvement plan for the area formulated using the management methods outlined in the foregoing "Conclusions" section of this report and coordinated among the specific Federal, State and local interests identified, would produce positive impacts and thus enhance the recreational and aesthetic values of the lake.

C. E. EASTBURN
Colonel, Corps of Engineers
Commander and District Engineer

EXHIBITS

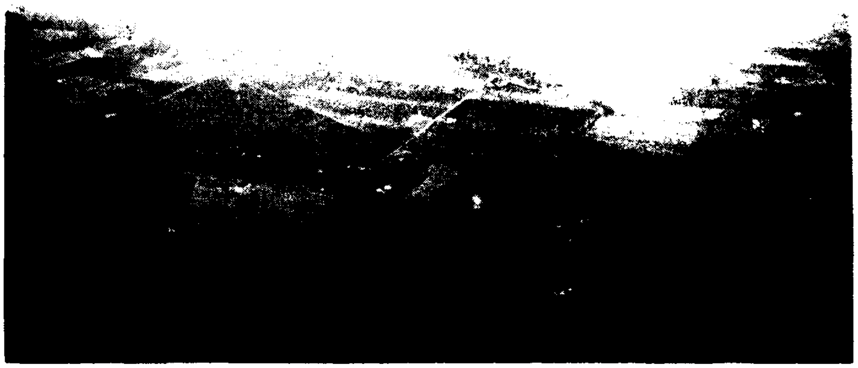


EXHIBIT NO. 1 Aerial view Grand Lake St. Marys

EXHIBIT NO. 2 View of Beaver Creek west from Meyers Road Bridge (April 1979)

EXHIBIT NO. 3 Low-lying developed area on south shore. Some riprap bank protection. (1979)

EXHIBIT NO. 4 East embankment recreation area showing sloughing banks, the result of waves overtopping riprap. (1979)

EXHIBIT NO. 5 View looking north along east embankment recreation area showing riprap and sloughing banks. (1979)

EXHIBIT NO. 6 Little Chickasaw Creek at S.R. 219 showing eroding banks 3,000 feet from lake. (1979)

EXHIBIT NO. 7 Eroding dredge spoil site, south shore (1978)

EXHIBIT NO. 8 Severe bank erosion on State-owned south shore lands.

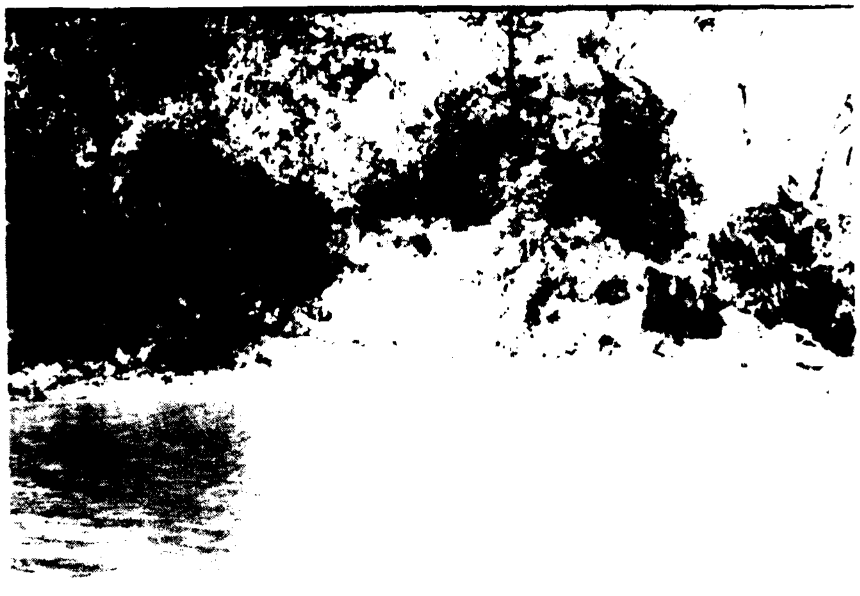


EXHIBIT NO. 9 Severe bank erosion on lake south shore channel inlet. (1979)

EXHIBIT NO. 10 Boat access channels requiring frequent maintenance dredging. (Dec. 1978)

EXHIBIT NO. 11 View of cleared portion of Beaver Creek approximately one mile from lake outlet. (1979)

EXHIBIT NO. 12 Grand Lake State Park on north side near Villa Nova. (1979)

EXHIBIT NO. 13 [illegible] Corner
[illegible]

EXHIBIT NO. 14 Western Embankment and Beaver [illegible] Outlet Channel,
City of Celina to the north (D[illegible] 79)

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AUG 81

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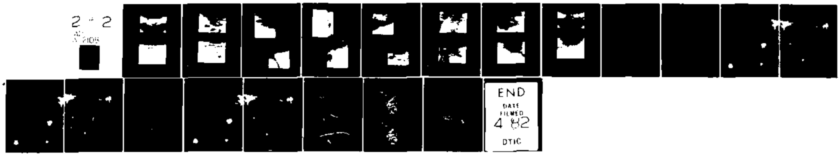
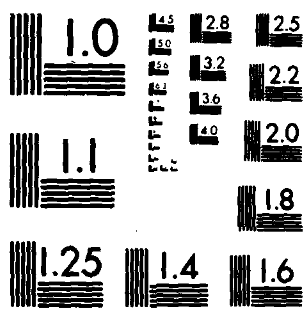




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

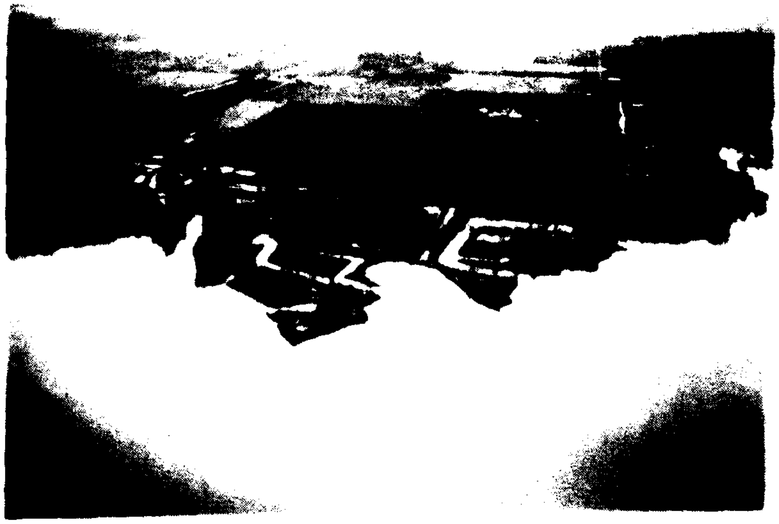


EXHIBIT NO. 15 Development and agricultural lands to the south, east of Windy Point Pier. (Dec. 1979)

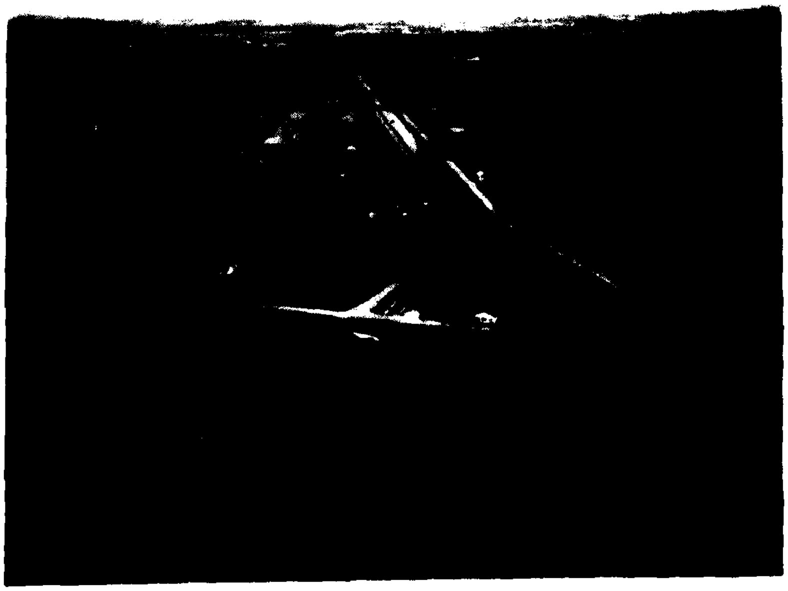


EXHIBIT NO. 16 East Embankment Outlet, St. Marys Feeder Canal and Fish Hatchery. (Dec. 1979)

EXHIBIT NO. 17 Grand Lake St. Marys looking to northeast, Montezuma Ba\ in foreground. (Dec. 1979)

EXHIBIT NO. 18 State Campgrounds and Beach on north shore. (Dec. 1979)

EXHIBIT NO. 19 Western Embankment and Beaver Creek Outlet Channel. (Dec 1979)

EXHIBIT NO. 20 Western end of Grand Lake and City of Celina (Dec. 1979)

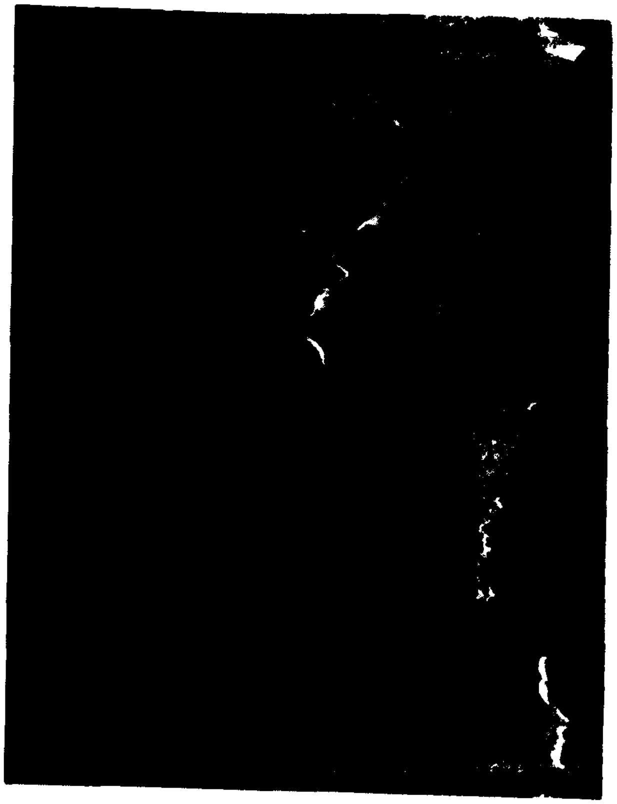


EXHIBIT NO. 21 Wave action and shallow lake areas on north shore, Vicinity of Holiday Park. (Dec. 1979)

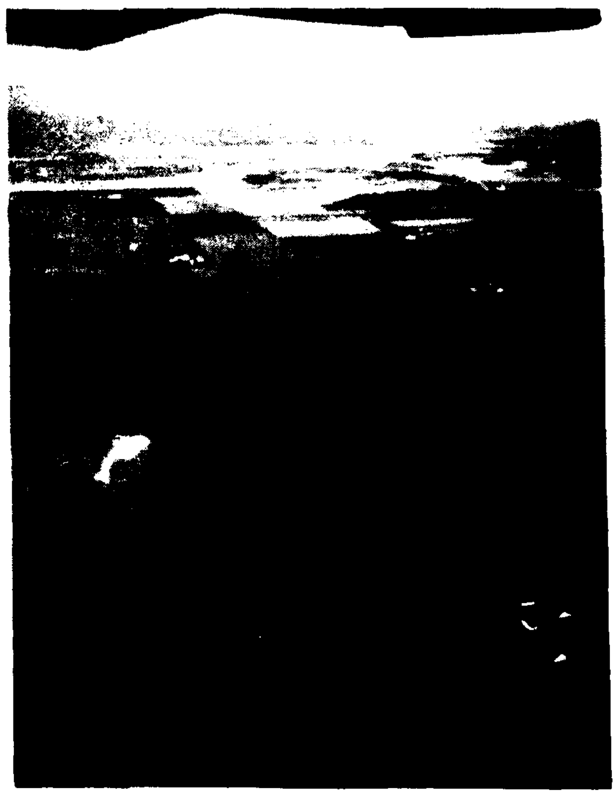


EXHIBIT NO. 22 Chickasaw Creek winding through prime farmland. Lake is on the horizon. (Dec. 1979)

EXHIBIT NO. 23 Windy Point Pier and Recreation Area (Dec. 1979)

EXHIBIT NO. 24 Southwest corner of lake at mouth of Coldwater Creek. (Dec. 1979)

EXHIBIT NO. 25 View of Mercer County Waterfowl Refuge, Route 703 in foreground, Montezuma Bay in background. (Dec. 1978)

EXHIBIT NO. 26 Chickasaw Creek winding through prime agricultural land south of the lake. Lake on the horizon. (Dec. 1978)

EXHIBIT NO. 27 Mouth of Coldwater Creek at southwest corner of lake. Sedi..ient input to the lake. (Dec. 1978)

EXHIBIT NO. 28 Beach at State Park on north shore showing good example of protection from wave action. (Dec. 1978)

EXHIBIT NO. 29 South shore developments (Moorman Road, Bayview) and adjacent agricultural lands. (Dec. 1978)

EXHIBIT NO. 30 Western Embankment. Celina, Ohio, at top and public land development in lower left corner. (Dec. 1978)

PLATES

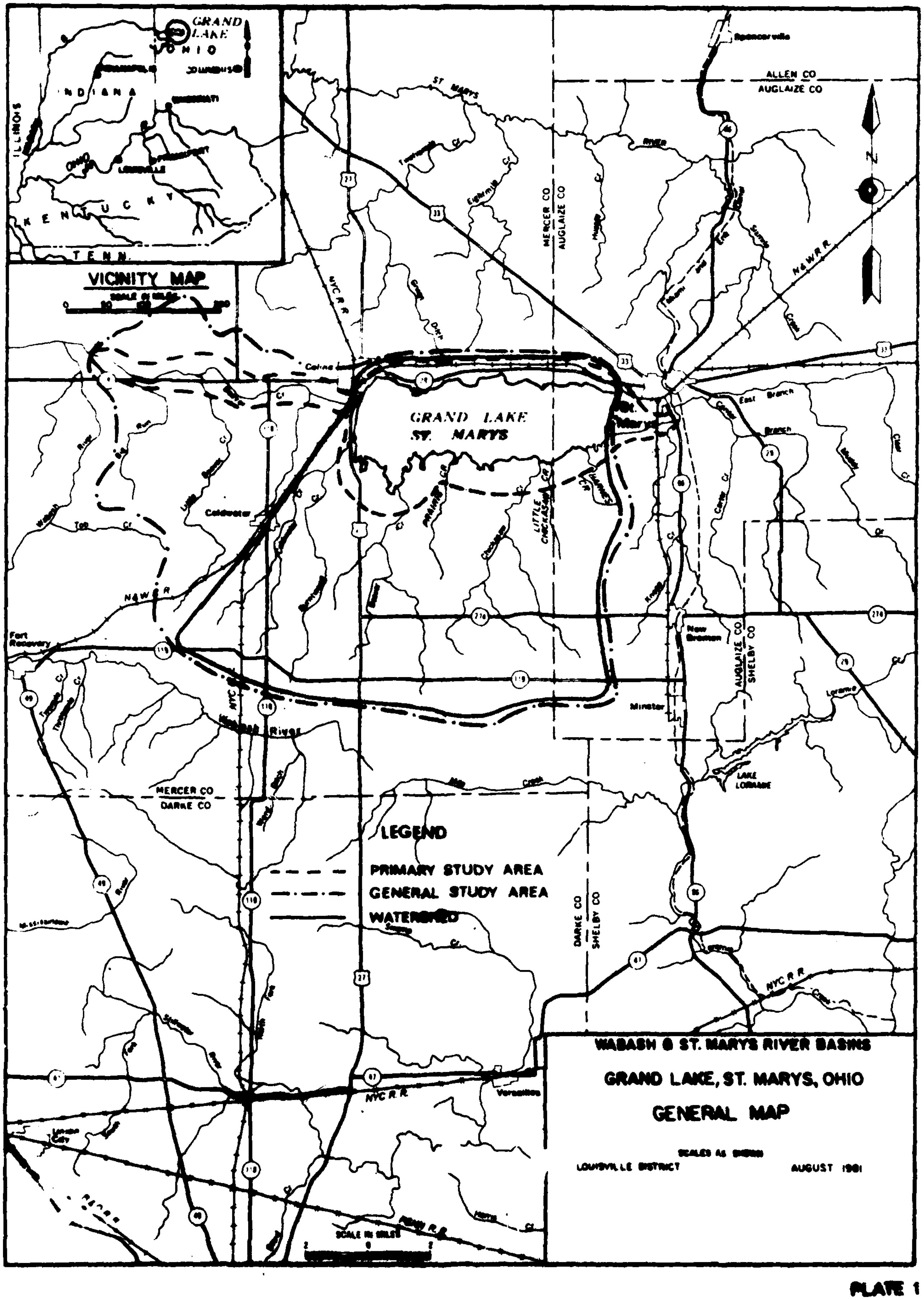
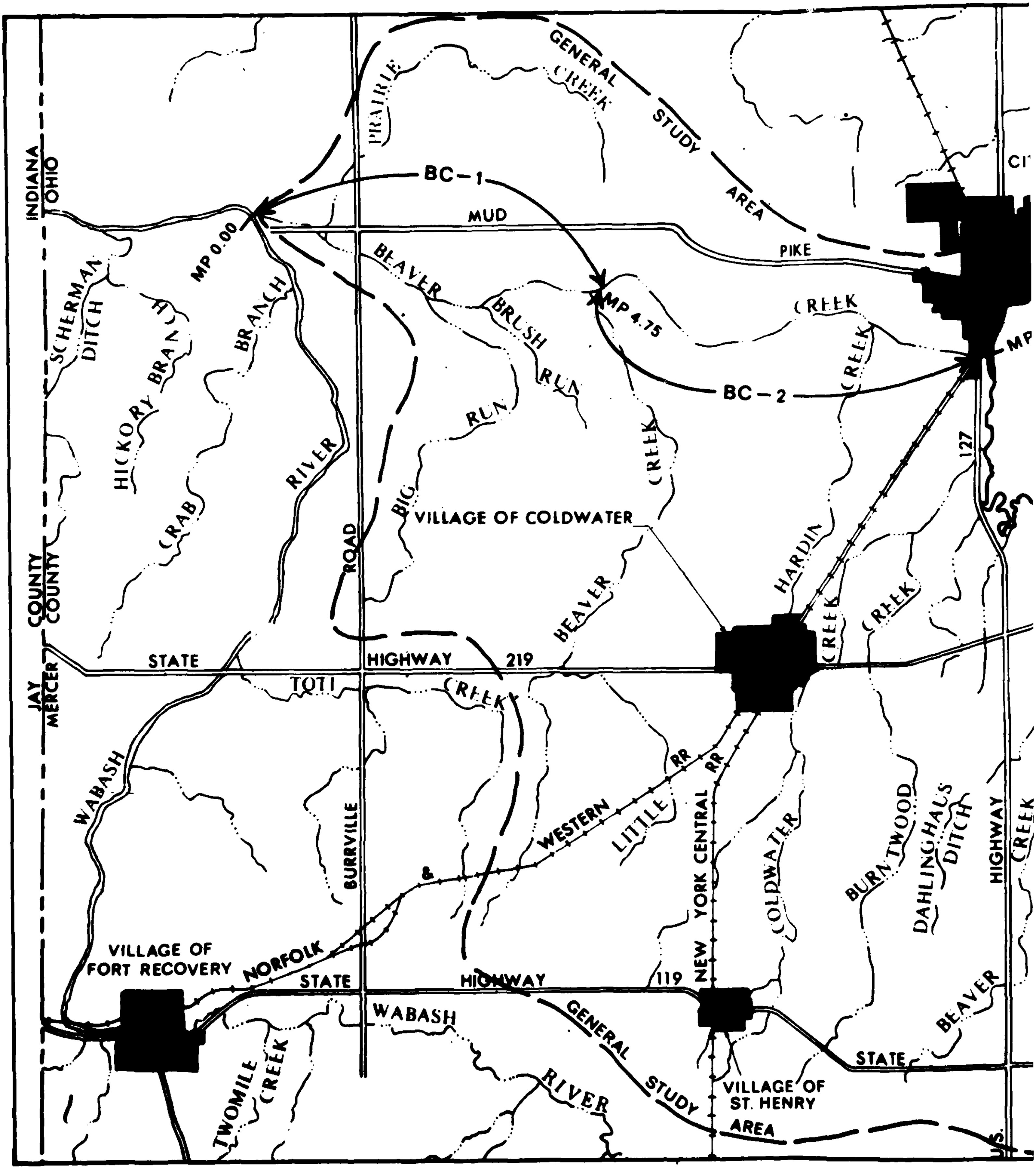
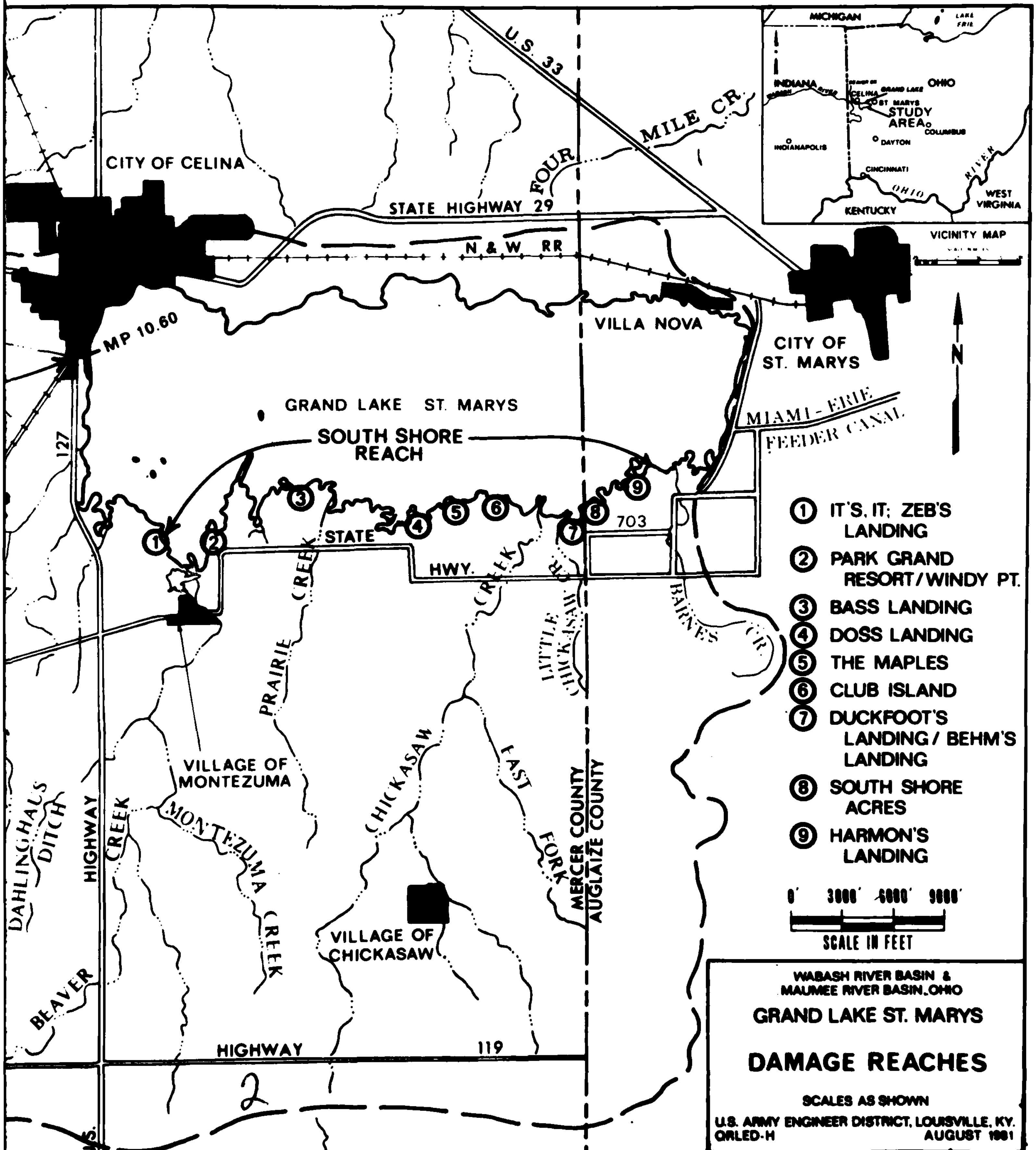

VICINITY MAP
OHIO
INDIANA
KENTUCKY
TENN.
ILLINOIS
GRAND LAKE
Spencerville
ALLEN CO
AUGLAIZE CO
MERCER CO
AUGLAIZE CO
ST MARYS
RIVER
NYC R.R.
N&W R.R.
GRAND LAKE
ST. MARYS
Celina
Coldwater
Fort Recovery
New Bremen
Minster
AUGLAIZE CO
SHELBY CO
LAKE LORAMIE
MERCER CO
DARKE CO
DARKE CO
SHELBY CO
Wabash River
Versailles
LEGEND
PRIMARY STUDY AREA
GENERAL STUDY AREA
WATERSHED
WABASH & ST. MARYS RIVER BASINS
GRAND LAKE, ST. MARYS, OHIO
GENERAL MAP
SCALES AS SHOWN
LOUISVILLE DISTRICT
AUGUST 1981
SCALE IN MILES

PLATE 1

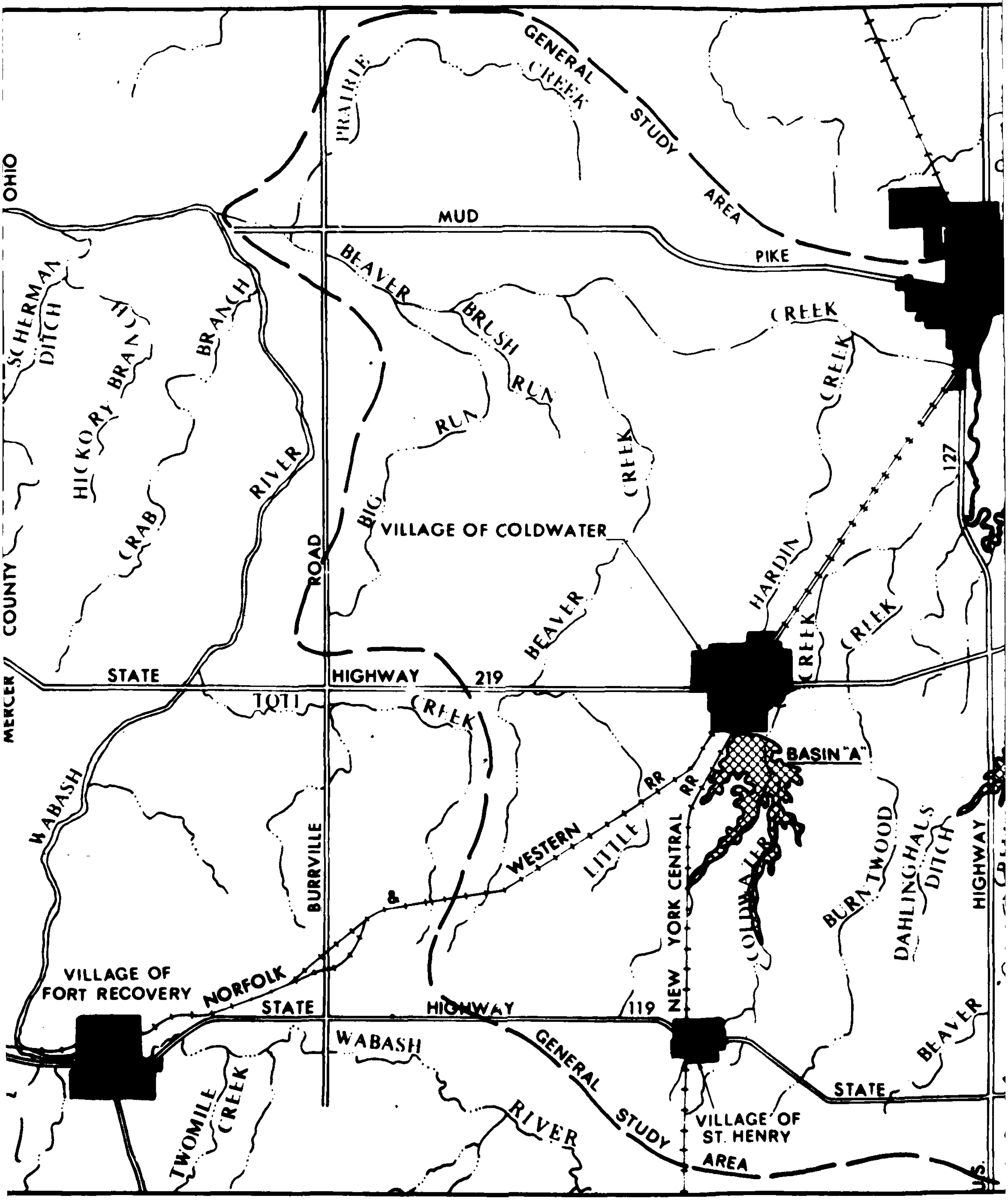


INDIANA
OHIO
JAY COUNTY
MERCER COUNTY
GENERAL STUDY AREA
PRAIRIE
CREEK
BC-1
BC-2
MUD
PIKE
MP 0.00
MP 4.75
BEAVER
BRUSH
RUN
CREEK
SCHERMAN DITCH
HICKORY BRANCH
BRANCH
CRAB
RIVER
BIG
ROAD
VILLAGE OF COLDWATER
HARDIN
CREEK
127
STATE HIGHWAY 219
TOTI CREEK
WABASH
BURRVILLE
NORFOLK & WESTERN RR
LITTLE
NEW YORK CENTRAL RR
COLDWATER
BURNTWOOD
DAHLINGHAUS DITCH
HIGHWAY
VILLAGE OF FORT RECOVERY
STATE HIGHWAY 119
WABASH RIVER
TWOMILE CREEK
VILLAGE OF ST. HENRY
STATE
AREA

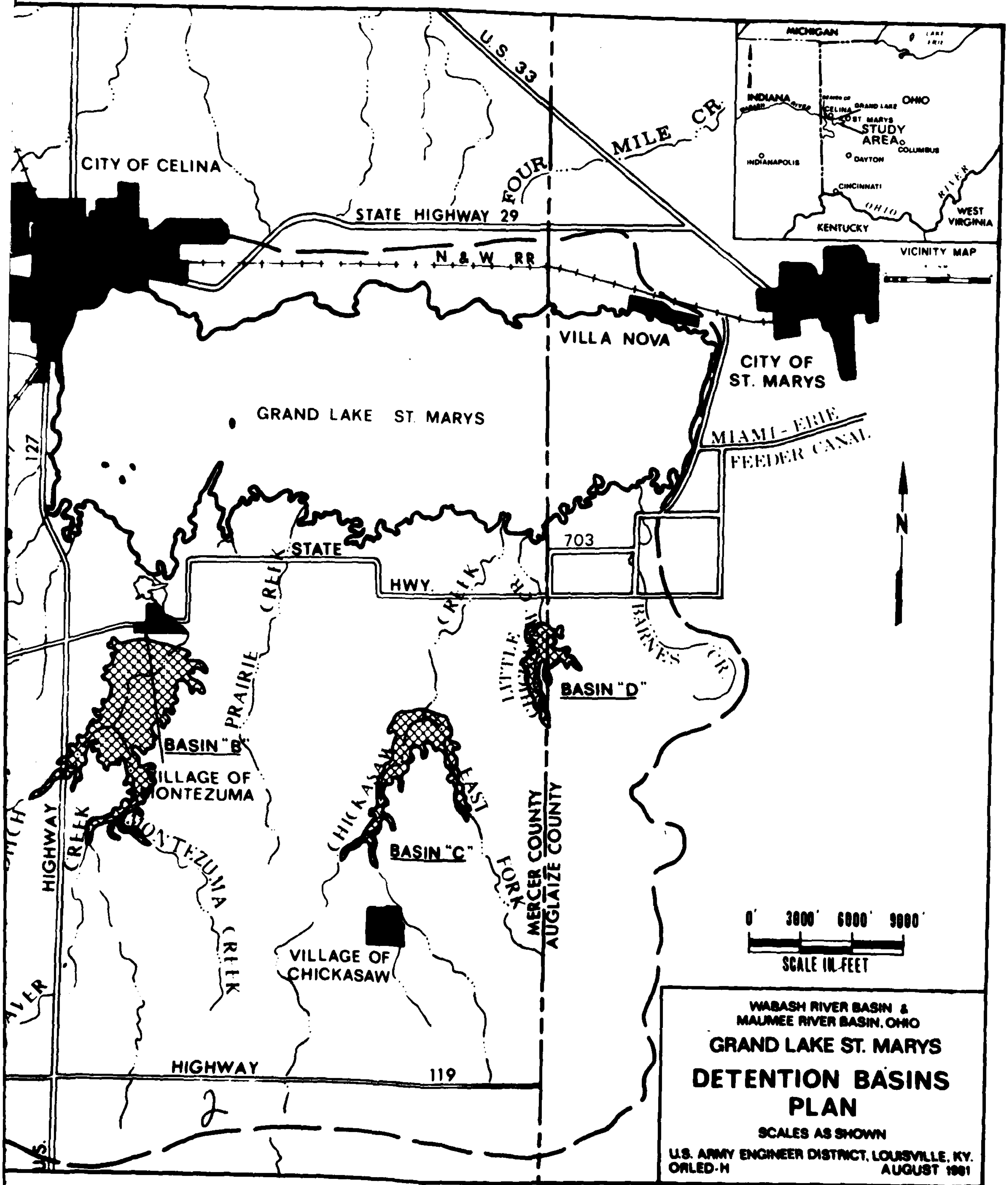


MICHIGAN
LAKE ERIE
INDIANA
OHIO
CELINA
GRAND LAKE
ST MARYS
STUDY AREA
COLUMBUS
INDIANAPOLIS
DAYTON
CINCINNATI
OHIO
RIVER
KENTUCKY
WEST VIRGINIA
VICINITY MAP
U.S. 33
FOUR MILE CR.
CITY OF CELINA
STATE HIGHWAY 29
N & W RR
MP 10.60
VILLA NOVA
CITY OF ST. MARYS
N
GRAND LAKE ST. MARYS
SOUTH SHORE REACH
MIAMI - ERIE FEEDER CANAL
127
STATE
HWY.
703
PRAIRIE CREEK
CREEK
LITTLE CHICKASAW CR.
BARNES CR.
1 IT'S, IT; ZEB'S LANDING
2 PARK GRAND RESORT/WINDY PT.
3 BASS LANDING
4 DOSS LANDING
5 THE MAPLES
6 CLUB ISLAND
7 DUCKFOOT'S LANDING / BEHM'S LANDING
8 SOUTH SHORE ACRES
9 HARMON'S LANDING
VILLAGE OF MONTEZUMA
DAHLINGHAUS DITCH
HIGHWAY
CREEK
MONTEZUMA CREEK
CHICKASAW
EAST FORK
MERCER COUNTY
AUGLAIZE COUNTY
0' 3000' 6000' 9000'
SCALE IN FEET
VILLAGE OF CHICKASAW
BEAVER
HIGHWAY 119
WABASH RIVER BASIN & MAUMEE RIVER BASIN, OHIO
GRAND LAKE ST. MARYS
DAMAGE REACHES
SCALES AS SHOWN
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H
AUGUST 1981

PLATE 2



GENERAL STUDY AREA
PRAIRIE CREEK
MUD PIKE
BEAVER CREEK
BRUSH RUN
BIG RUN
SCHERMAN DITCH
HICKORY BRANCH
CRAB BRANCH
RIVER
OHIO
MERCER COUNTY
ROAD
VILLAGE OF COLDWATER
CREEK
HARDIN CREEK
127
STATE HIGHWAY 219
TOTI CREEK
BASIN "A"
WABASH
BURRVILLE
NORFOLK & WESTERN RR
LITTLE RR
NEW YORK CENTRAL RR
COLDWATER
BURNTWOOD
DAHLINGHAUS DITCH
HIGHWAY
VILLAGE OF FORT RECOVERY
STATE HIGHWAY 119
WABASH RIVER
TWOMILE CREEK
VILLAGE OF ST. HENRY
STATE
BEAVER



WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

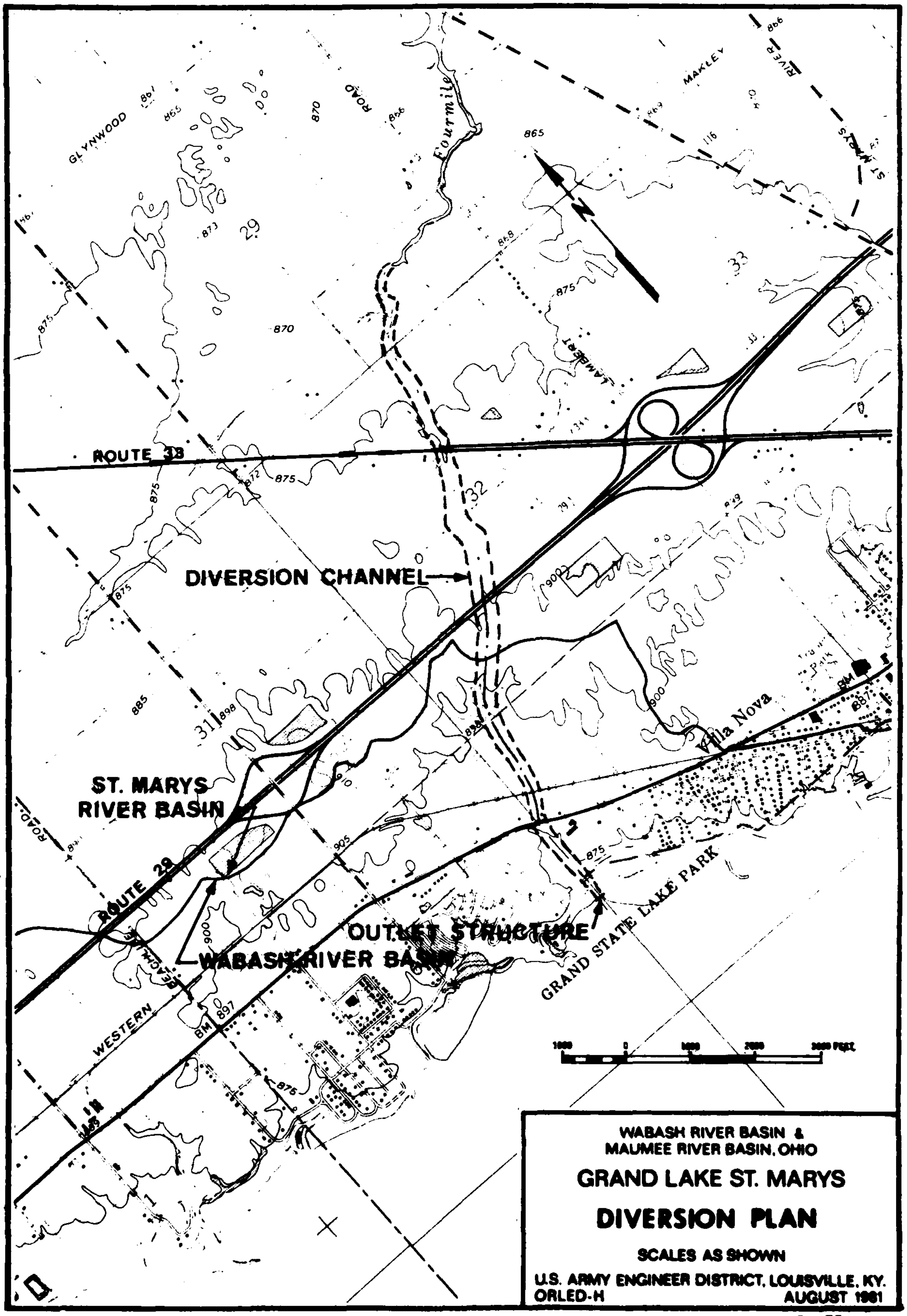
GRAND LAKE ST. MARYS

DETENTION BASINS PLAN

SCALES AS SHOWN

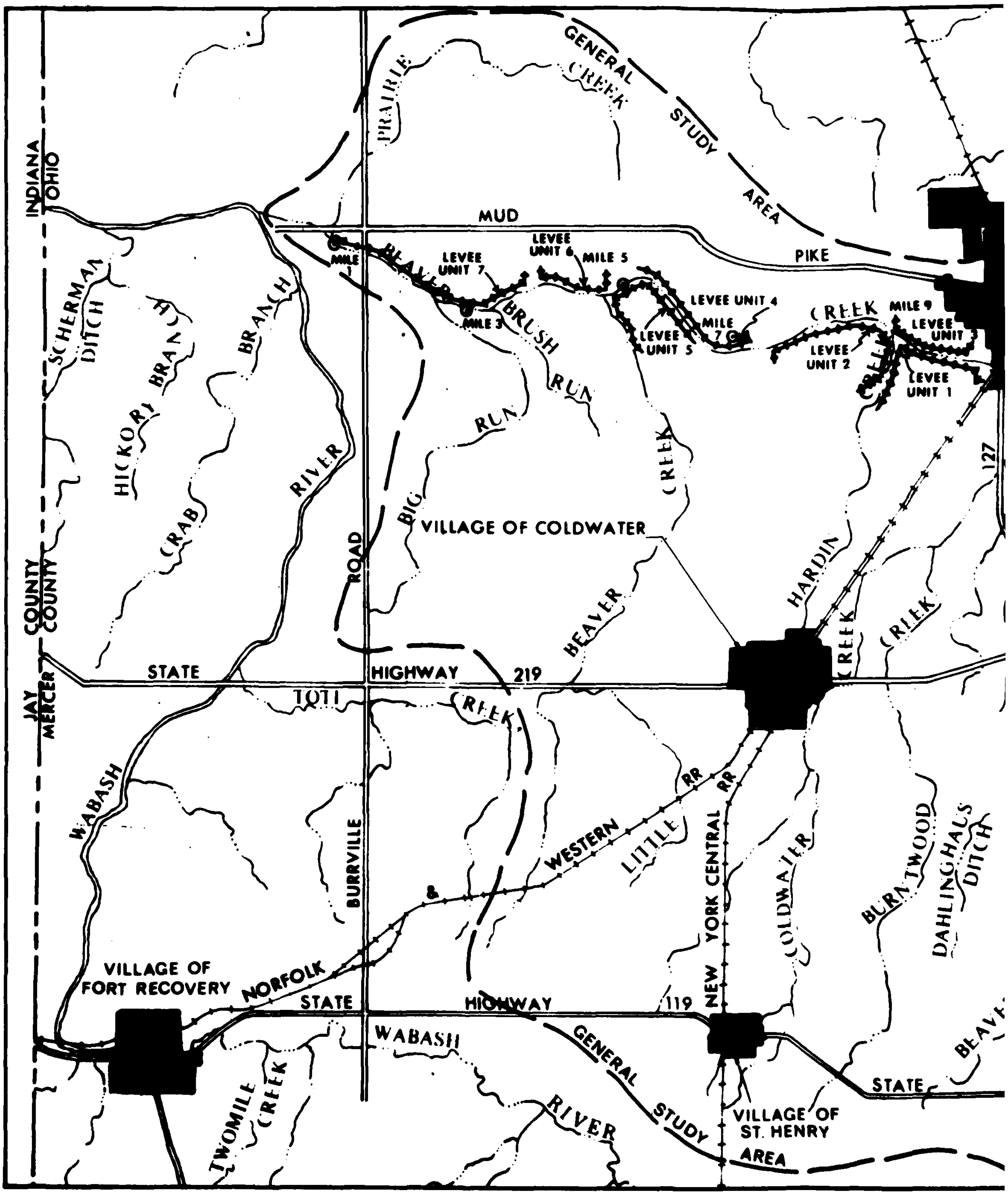
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H AUGUST 1981

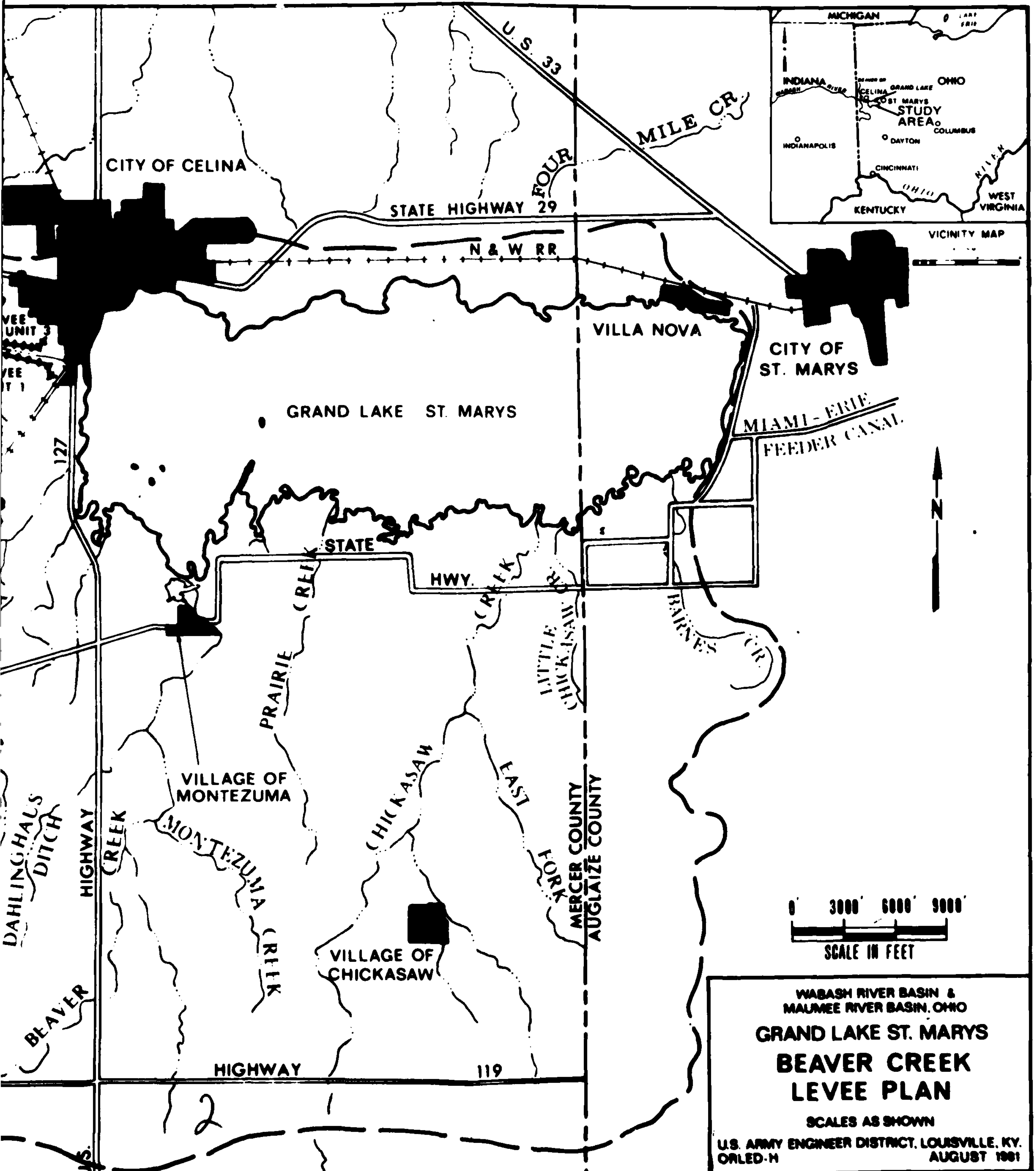
PLATE 3



GLYNWOOD
ROAD
Fourmile
MAKLEY
RIVER
ST MARYS
LAMBERT
ROUTE 33
DIVERSION CHANNEL
ST. MARYS
RIVER BASIN
ROUTE 29
ROAD
BEACH
WESTERN
OUTLET STRUCTURE
WABASH RIVER BASIN
Villa Nova
GRAND STATE LAKE PARK
29
33
32
31
875
870
865
900
905
897
BM
WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO
GRAND LAKE ST. MARYS
DIVERSION PLAN
SCALES AS SHOWN
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H
AUGUST 1981

PLATE 4


INDIANA
OHIO
JAY COUNTY
MERCER COUNTY
GENERAL STUDY AREA
PRAIRIE
CREEK
MUD
PIKE
LEVEE UNIT 7
LEVEE UNIT 6
MILE 1
MILE 3
MILE 5
MILE 7
MILE 9
LEVEE UNIT 4
LEVEE UNIT 5
LEVEE UNIT 2
LEVEE UNIT 1
LEVEE UNIT
BEAVER
BRUSH RUN
CREEK
SCHERMAN DITCH
HICKORY BRANCH
BRANCH
CRAB
RIVER
BIG RUN
ROAD
VILLAGE OF COLDWATER
HARDIN
CREEK
127
BEAVER
STATE HIGHWAY 219
TOTI CREEK
WABASH
BURRVILLE
WESTERN
LITTLE
RR
NEW YORK CENTRAL
COLDWATER
BURNTWOOD
DAHLINGHAUS DITCH
NORFOLK
VILLAGE OF FORT RECOVERY
STATE HIGHWAY 119
WABASH
RIVER
TWOMILE CREEK
VILLAGE OF ST. HENRY
STATE
GENERAL STUDY AREA



WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

BEAVER CREEK LEVEE PLAN

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H AUGUST 1981

PLATE 5

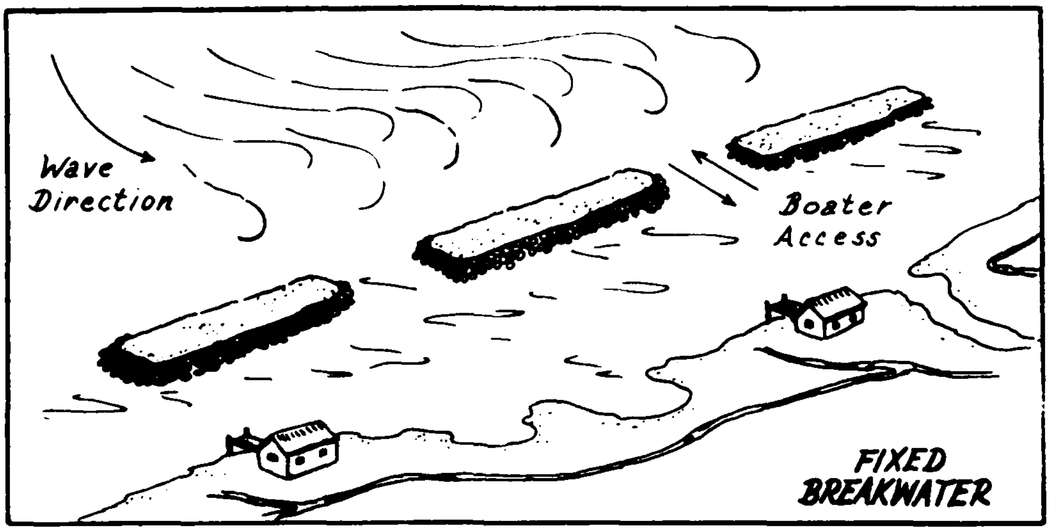


FIGURE 6A

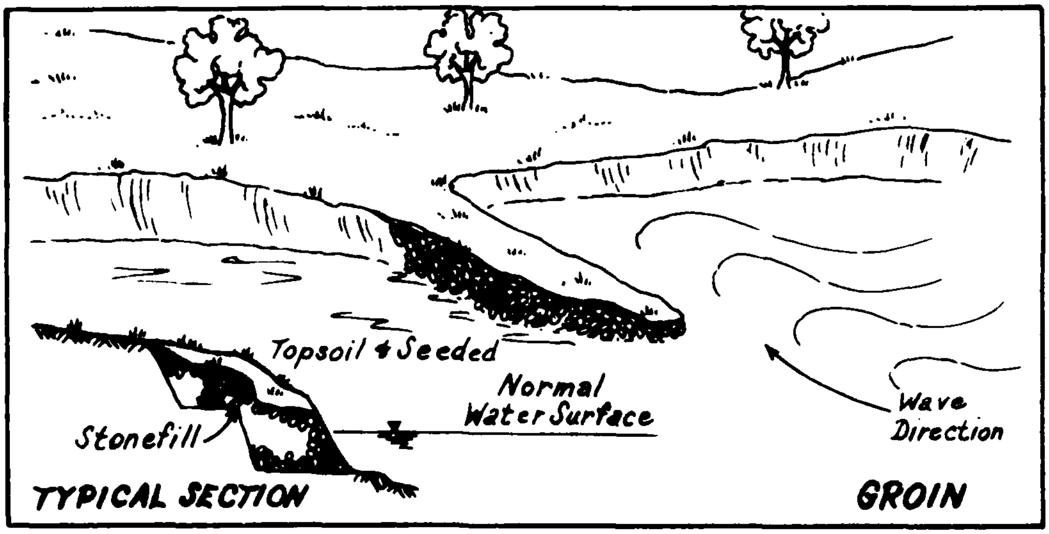


FIGURE 6B

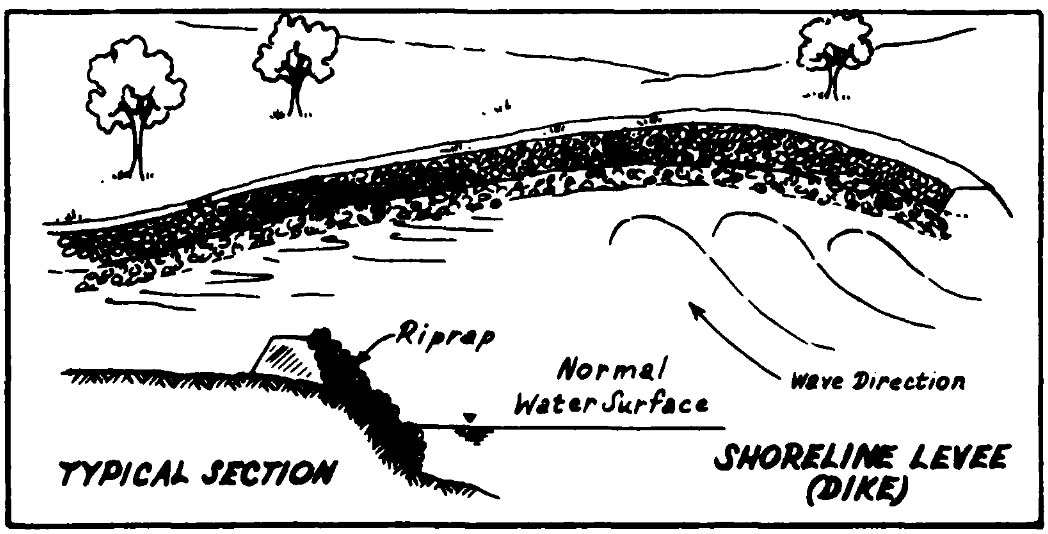
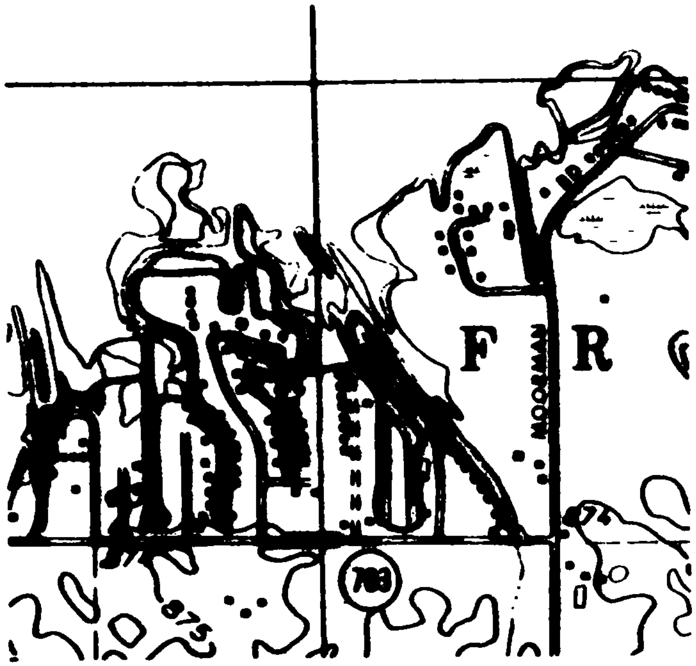


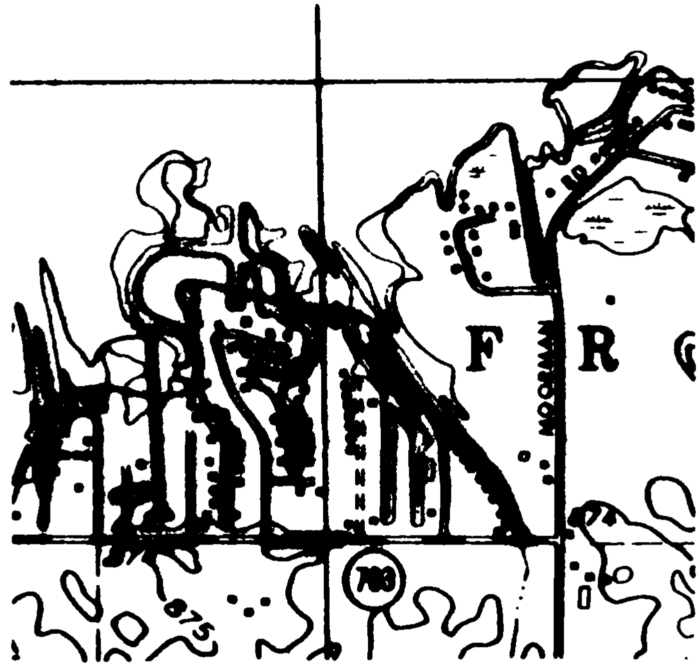
FIGURE 6C

LEGEND

LEVEE



ACCESS CHANNELS MAINTAINED



LEVEES ACROSS ACCESS CHANNELS

TYPICAL LEVEE REQUIREMENT (WEST OF MOORMAN ROAD)

SCALE : 1" = 1000'

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

SHORELINE LEVEE PLAN

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H AUGUST 1981

PLATE 7

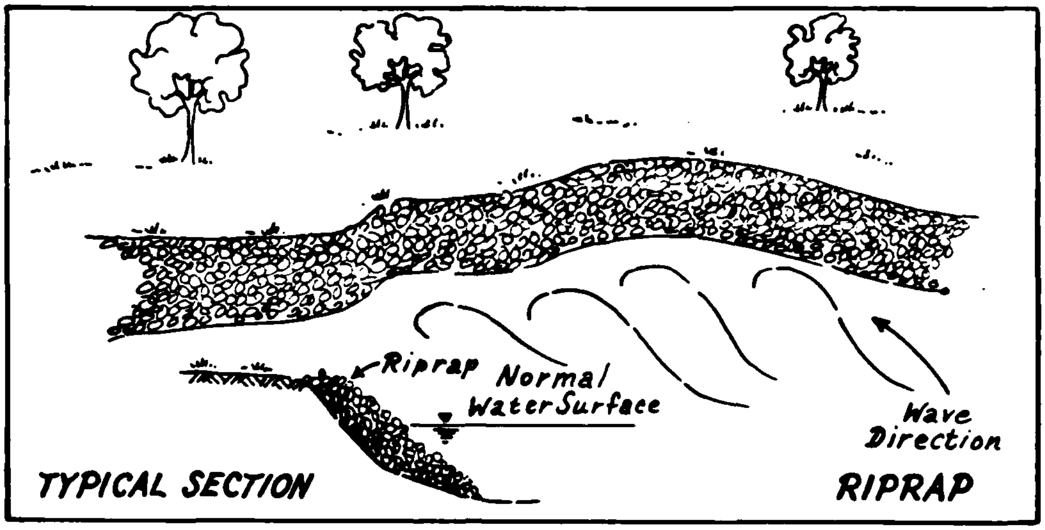


FIGURE 8A

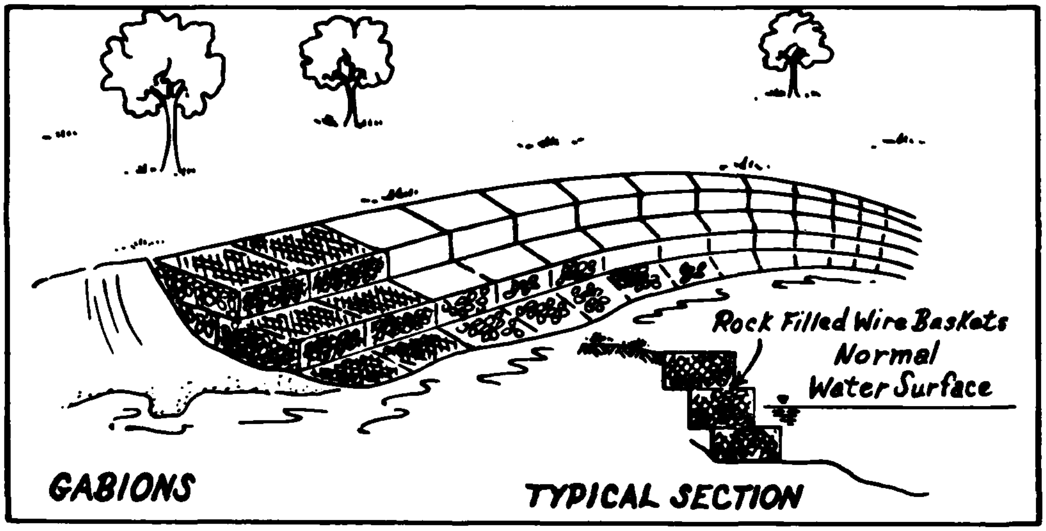


FIGURE 8B

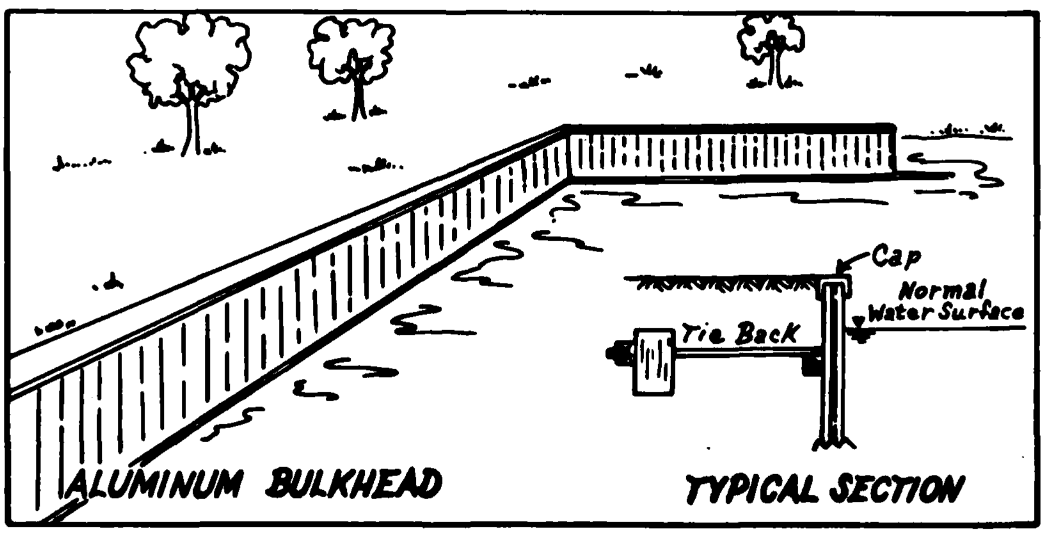


FIGURE 8C

SHORELINE EROSION CONTROL

ATE

LME

8