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US Army Corps of Engineers
Huntington District

Muskingum River Basin Systems Operations Study

Huntington District
Great Lakes and Ohio River Division
US Army Corps of Engineers
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MUSKINGUM RIVER BASIN INITIATIVE

EXECUTIVE SUMMARY

"As the Nation grows and grows older, the adequacy and condition of its public works infrastructure is an increasing concern. Underlying this concern is the further concern that some projects may not be fulfilling their original purposes." – Revitalization of Corps of Engineers Projects, Institute of Water Resources Report 03-PS-1, April 2003.

People of the Muskingum River Basin, Ohio are protected by a system of sixteen flood control projects, most built in the 1930s, known as the Muskingum River Basin Flood Control System. Constructed, owned, and operated by the U.S. Army Corps of Engineers (USACE) in partnership with the Muskingum Watershed Conservancy District (MWCD), the two agencies are currently leading a multi-agency Oversight Committee to plan a collaborative, long-term strategy for renewal known as the "Muskingum River Basin Initiative" (MRBI). The primary goal of this initiative is to develop a comprehensive plan to revitalize the aging flood control system through infrastructure renewal to ensure public safety, and to improve water quality and other environmental resources through ecosystem restoration. The key challenge for the Committee will be to maintain the proper balance between flood protection, recreation, water, and land use to optimize the valuable resources within the basin. Funds are needed immediately to initiate revitalization of the basin. A steady funding stream over the next 10-15 years would support many of the highest priority goals of the MRBI. Needs in the basin have been prioritized and funding is being pursued under appropriate existing authorities. However, a special Congressional appropriation appears to be the only means of securing sufficient funds to meet the crucial needs of the basin.

Background to flood control in the Muskingum River Basin - The MWCD was formed in 1933, to function as a political subdivision of the State of Ohio to plan, construct, and administer flood-control and conservation projects, and has been a major partner with USACE since its inception. Fourteen of the Muskingum projects were funded through the Public Works Administration and are recognized as some of the most successful New Deal initiatives of the 1930's. Nationwide, it was the first system designed to impound water for regional flood control and has served as a model of multipurpose water management. This system was designed to serve the Muskingum River Basin for 50 years but now almost seven decades have passed and the system is showing its age. For 70 years this system has protected the region from flooding and provided opportunities for recreation throughout thousands of acres of land and water. But, like an early 20th century home in need of major renovations, the system is in need of urgent repairs, restoration, and modernization to be effective in the 21st century.

Nevertheless, the reservoirs have been operated much the same since their construction in the 1930s. Demand on these projects has increased and has compounded with age, while operation and maintenance funding has remained relatively the same. Short-term fixes, funded from limited revenue sources, have managed to keep the system functional. But some features no longer provide for public safety as originally authorized so now revitalization – not simply maintenance – is required. The entire system must be renewed. The USACE has identified hundreds of projects, large and small, many of which are critical to public and environmental safety. A comprehensive infrastructure report has been prepared listing structural deficiencies of the 16 flood control projects. However, these preliminary efforts are small in comparison to the structural and environmental improvements that are needed.

No example illustrates the urgency for modernization better than the winter storm events experienced in 2005. During the months of December 2004 and January 2005, a series of storms over a two-week timeframe inundated the Basin resulting in the largest flood event since the devastating flood of March 1913. The 1913 Flood led to the construction of the Muskingum Reservoir System. During the winter 2005 event, pools of record occurred at 7 of the 16 Muskingum reservoirs and significant operational and safety issues were encountered. Because of concern over these aging structures, the USACE deployed engineering staff to continually monitor the dams to ensure public safety and be in position to provide early warning should a dam's structural integrity become compromised. In fact, Bolivar Dam experienced significant seepage to such an extent that failure of the dam was believed to be highly probable and additional rainfall and flooding within the basin would have almost certainly led to evacuations of downstream communities. The reservoirs prevented over $417 million in damages, and the flood brought to the forefront many of the problems with these 70-year-old flood-control structures which, if left in their present condition, will compromise the public's safety. This event along with other recent natural disasters such as the devastating hurricanes of 2005, have brought national attention to the importance of the Nation's infrastructure to public safety, the environment, and the economy.

Critical Infrastructure - In June 2005, USACE began evaluating the Nation's reservoir and lock and dam projects with known dam safety concerns to develop relative ratings for human and economic risk. The effort, called the Screening Portfolio Risk Analysis (SPRA), is being used as a tool to help shape USACE budget decisions regarding reservoir and lock and dam infrastructure improvements. The SPRA evaluated over 60 USACE projects nation-wide, and ranked four Muskingum projects in the top 20 for highest risk. The respective rankings are: Mohawk #7, Dover #9, Bolivar #11, and Beach City #18.

Asset Management Plan - Before much of the necessary work is initiated, an Asset Management Plan should be prepared to lay down a proper foundation that will directly support the required engineering analyses, modeling, and designs, all of which will be critical for the systematic revitalization of the Muskingum Basin. This foundation includes conducting basin surveys, preparing updated digital mapping, establishing a geospatial information system, developing a comprehensive hydraulic model of the Muskingum drainage basin, and overhauling the existing real-time stream monitoring network.

Flood Damage Reduction – Over the last seven decades significant physical, economic and environmental changes have occurred within the Muskingum Basin. However, the flood control system is being operated now just as it was in the 1930s. USACE has evaluated potentially beneficial project operation and regulation procedures for the purpose of optimizing system efficiency. The main considerations during this evaluation were economic impacts, water control impacts and water supply allocations. This optimization study concluded that repair of the structural deficiencies at Bolivar Dam and Dover Dam would most significantly reduce downstream flood damages. The next most beneficial changes would include modifications to the siphons at Tappan, Clendening and Piedmont to reduce flood damages in the communities downstream of those projects.

A major detriment to successful flood management is reduced retention capacity at several reservoirs due to sedimentation. Beach City has already lost its conservation pool due to sedimentation, and several other Muskingum lakes are rapidly filling up with sediments. Dredging is the most likely means for restoring the original storage capacities of the lakes.

Implementation of a modern and coordinated Muskingum Basin Flood Warning System is a key component of the revitalization and renewal strategy of the MRBI and is a long overdue component of Muskingum Basin flood control operations. A Flood Warning System Report has been prepared which outlines a flood warning plan for the basin that will facilitate communication among Federal, state, and local emergency agencies in addition to alerting the basin's residents of a flood emergency.

Environmental Restoration - Water quality in the Muskingum River Basin is a pressing concern to the environment and to public health and welfare. During the summer months, lower depths of several reservoirs form high levels of hydrogen sulfide. Since the outlet structures release water from these depths, the tail waters of these reservoirs contain high amounts of hydrogen sulfide. This poses public health and structure deterioration concerns. Therefore, there is a need to construct selective withdrawal systems at these projects. The USACE has prepared a preliminary design solution to modify the outlet structures to remediate the hydrogen sulfide problem and to repair the deteriorated infrastructure. The U.S. Environmental Protection Agency has determined acid mine drainage (AMD) to be the number one water quality problem in Appalachia. The Ohio Department of Natural Resources estimated that there are 180 abandoned mined land sites upstream of the Muskingum reservoirs. In addition to AMD, the Ohio Environmental Protection Agency indicates a significant number of the basin's municipalities' water and wastewater infrastructure are in violation of public health criteria and are also contributing to degraded water quality. Currently, USACE administers a Section 594 Program to provide technical and funding assistance to Ohio municipalities for infrastructure projects. A priority for this program will be sites affecting water quality of the Muskingum watershed, especially since these resources will likely be relied upon to meet the future demands for water supply.

Plan of Action - The Muskingum River Basin Initiative Report serves as the initial phase of the process to revitalize the Muskingum Reservoir System. It develops a preliminary plan of action for proceeding with projects under existing Corps authorities, and supports a legislative initiative for a comprehensive study with General Investigations funding. It documents the findings and assesses the current needs in the basin through a multidisciplinary strategy and a multifunctional team. The scope of renewal and revitalization is robust, multi-faceted, and estimated to cost more than $2 billion spanning several decades to complete. The next phase would be the detailed study stage in which the Corps of Engineers would undertake a comprehensive assessment to further define and quantify the potential scope of problems and opportunities. Detailed studies to address the needs identified in the MRBI report could proceed under existing USACE authorities with multiple sources of funding - mainly the very limited operations and maintenance funds - or the Corps could await authorization of a comprehensive study before proceeding. The final phase of the process would be the implementation stage. In this phase the Corps would implement the program plan of action by proceeding without specific program authorization using existing authorities requiring feasibility reports to Congress on a project-by-project basis, or be directed to implement a comprehensive program following Congressional authorization. The USACE believes the most efficient means to address the revitalization of the Muskingum Basin is through a comprehensive program.

It was in the national interest – and in the interest of the state, the region and local communities – to support construction of the Muskingum River Basin system in the 1930s. Now, especially in light of recent national attention to the importance of flood control infrastructure, it is time to reinvest into these resources to preserve, protect and enhance this nationally significant and economically important system. Partners are working to gain the long-term commitment from citizens, landowners, industries and businesses, and from government officials at all levels to extend the life of the valuable and vitally important Muskingum River Basin Flood Control System.

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1. Introduction

a. Purpose of Report

The Muskingum River Basin multi-purpose reservoir system consists of 14 projects originally constructed in the 1930's and two additional projects constructed in 1959 and 1972. Development of this reservoir system was a joint effort of the U.S. Army Corps of Engineers (USACE) and the Muskingum Watershed Conservancy District (MWCD). Most of these projects are now 70 years old, and although they have served the nation well, there are major problems associated with the conditions of the structures as well as the physical changes that have occurred in the Muskingum Basin since the projects were constructed. This report provides information on the present reservoir system, summarizes the current problems related to the age of the projects, and identifies the significantly changed conditions throughout the Basin. This report also will address the impacts that the current problems are having on the capacity of the projects to accomplish their authorized project purpose. Routine maintenance provides a basis for addressing some of the minor problems, but there is a need for a comprehensive review with public participation of the entire 70-year-old system to understand the varying significant issues and develop an acceptable revitalization plan. "Revitalization" is meant to imply the improvement and/or increase in beneficial outputs, short of project replacement. Revitalization encompasses rehabilitation and restoration, but also includes increased or new beneficial use of underutilized assets. Although this is not a formulation document, there is discussion on the various alternatives available for revitalizing the aging structures and addressing other significant problems at the reservoir projects. This report also includes discussion of environmentally-related problems occurring throughout the entire Muskingum River Basin. The overall goal of this initiative is to develop a general plan to revitalize this aging reservoir system through infrastructure renewal to ensure public safety and to improve water quality and other environmental resources through ecosystem restoration. This report is intended to be the initial planning document which will lead to Congressional authorization and funding of a comprehensive basin investigation through the General Investigation Program.

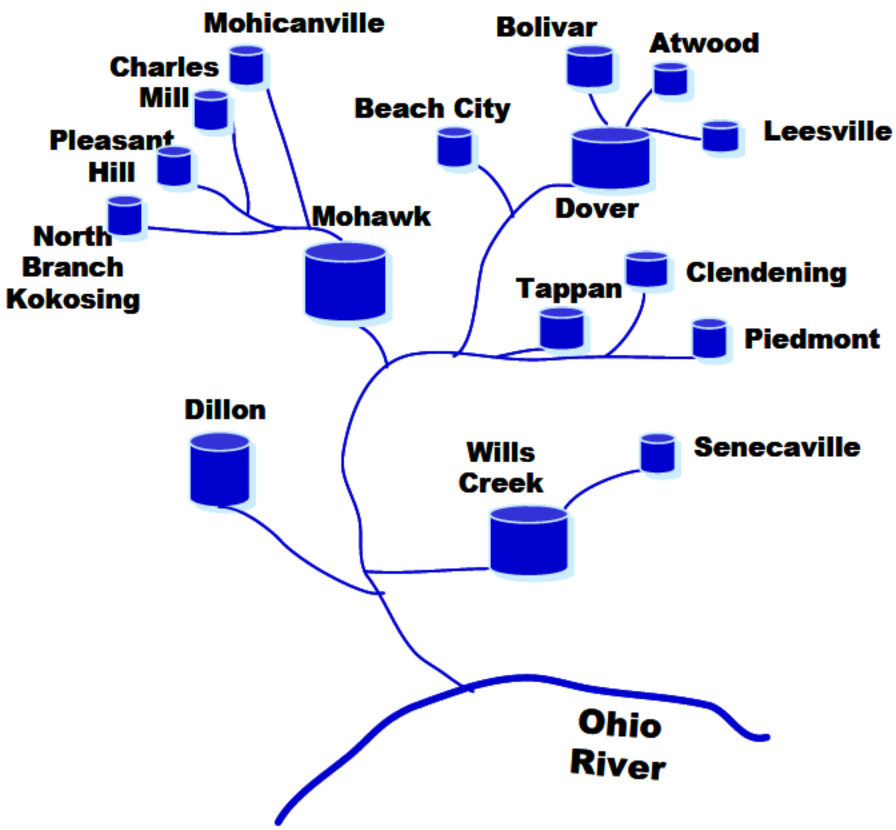
b. Background

The Muskingum River Basin is the largest watershed in the State of Ohio, amounting to about 20 percent of the state's land area. The flood of 1913 caused widespread damage in the basin, and following this major storm event there was a regional effort to develop measures to prevent, or at least reduce, flood damages. The State of Ohio participated in the investigation and, as a result, the MWCD was formed as a separate political sub-division of the State in June 1933. The purpose was to develop and implement a comprehensive plan for flood control in the 18-county area which made up the Muskingum River Basin. The MWCD prepared a basin-wide reservoir plan and submitted it to the Public Works Administration which had been created as a Federal initiative to help alleviate unemployment problems. The PWA granted funds to the U.S. Army Corps of Engineers in December 1933 for design and construction of the MWCD reservoir plan. A contract was executed between the Corps and the MWCD in 1934 and the USACE's Zanesville District was established to develop the final plans and oversee construction of the reservoir system. Construction was undertaken immediately and 14 of the dams were completed by 1938 and turned over to the MWCD for operation. This cooperative effort between the Corps and the MWCD produced a multi-purpose flood control reservoir system. Several of the reservoirs were formulated with large conservation pools, which provided for future uses such as water supply, recreation, and downstream flow augmentation. Dry dams were also part of the system. They had no lakes but retained flood flows during major storm events. The Flood Control Act (FCA) of 1939 included the completed 14 Muskingum Basin reservoirs as elements in the Ohio River Basin Flood Control plan which had been authorized by the FCA of 1938. The FCA of 1939 relieved the MWCD of the responsibility of operating and maintaining the dams, which since that time have been operated and managed by the Corps. The Federal Government has title to the lands occupied by the dams and appurtenant structures and manages the flowage easements for flood control operations. The MWCD owns the storage rights at the projects where there are conservation pools (lakes), and lands surrounding the lakes which it manages for recreation and conservation purposes.

Subsequent to construction of the 14 original MWCD reservoirs, two other multi-purpose reservoir projects were constructed in the Muskingum Basin by the USACE. Dillon Lake on the Licking River was completed in 1959, and North Branch of Kokosing Lake in the Walhonding River sub-basin was completed in 1972. These 16 reservoir projects that make up the Muskingum River Basin Flood Control System are shown on Figure 1. The Corps manages both of these projects; however, most of the project lands at Dillon Lake have been leased to the Ohio Department of Natural Resources (ODNR) for recreation use. Additionally, four local flood protection projects (LPPs) and several snagging and clearing projects have been constructed in the Muskingum Basin under the Corps' Continuing Authority Program.

Along the mainstem Muskingum River there is a system of ten antiquated navigation locks and dams originally constructed in the mid 1800's by the State of Ohio. The ODNR presently manages these projects for recreation navigation only.

Figure 1. The Muskingum River Basin Flood Control System.



c. Prior Studies and Reports

Investigations concerning the Muskingum River Basin have been made by the Corps of Engineers and other agencies since the 1930's. The original plan for the MWCD is of particular significance. The plans were completed in 1933 and resulted in the construction of the original system of 14 dams and reservoirs. The FCA of 1938 authorized seven additional projects; however, only Dillon Reservoir and three local protection projects were subsequently constructed.

The Kokosing River Basin Survey Report (HD-220) completed in 1960, recommended construction of the North Branch of Kokosing River Reservoir. The project was authorized by the FCA of 1962 and was completed in 1972.

The Licking River Basin Survey Report (HD-337) completed in 1967, recommended construction of Utica Reservoir on the North Fork of Licking River and modifications to the Newark Local Protection Project (LPP) which was initially constructed in 1941. The planning for Utica Reservoir is in an inactive status because of marginal economic feasibility. Modifications to Newark LPP were completed in 1990.

The Muskingum River Basin Report (HB 97-117) completed in 1978, recommended construction of Killbuck and Mansfield LPP's. Both projects were authorized in 1986 but never constructed.

At the request of the State of Ohio, a reconnaissance study to determine the Federal interest in rehabilitation of the original Muskingum River waterway navigation system was completed in 1991. The system is owned by the State of Ohio and operated by the ODNR as a state park. The report determined that although many of the structures are in a deteriorated condition, the Corps cannot participate in reconstruction because the locks and dams are not part of a commercial navigation system.

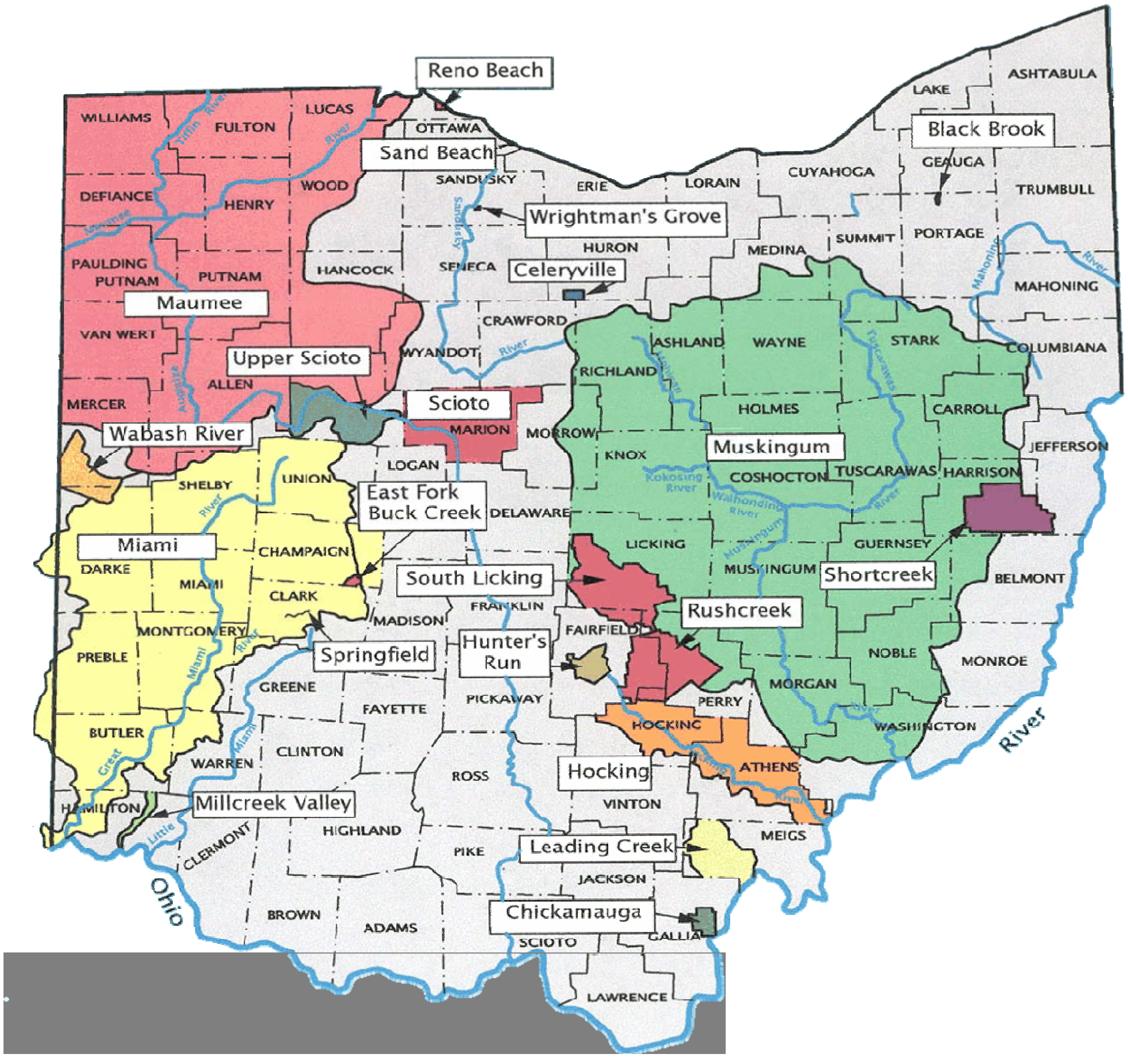
A Muskingum River Basin Survey Report was prepared in 1975 by the U.S. Department of Agriculture under the direction of the Soil Conservation Field Advisory Committee and in cooperation with the ODNR.

"Taming the Muskingum," is a history of the Muskingum River Basin development. This report was prepared by West Virginia University in the summer of 2002 and funded by the Corps.

d. Study Area

The Muskingum River Basin, with a drainage area of over 8000 square miles, is situated in the eastern portion of the State. The basin contains 6 counties and portions of 12 others and extends from the Ohio River at Marietta to within 25 miles of Lake Erie. (See Figure 2.) The basin has an estimated population of 2,000,000 people and contains two large cities, Akron and Canton, and several smaller cities including Mansfield, Newark, Dover, New Philadelphia, Zanesville and Marietta. Nearly half the population is in the northeastern counties of Summit, Stark and Medina. The southeastern portion of the basin is within the fringes of Appalachia where the population as well as economic growth have lagged the remainder of Ohio. Farming is a very important activity, accounting for about 60 percent of the basin's land use. Coal production is also important in the basin, particularly in eight southeastern counties. The impacts from farming and mining activities, particularly erosion, sedimentation, and acid mine drainage have resulted in significant changes in the natural environment of the basin. Most of the basin's high-quality streams are located in the northwestern portion of the watershed. The Nature Conservancy encourages protection of these steams which includes the Kokosing River, Kokosing North Branch, the Walhonding River, Clear Fork of the Mohican River and Wakatomika Creek.

Figure 2. The Muskingum River Basin



e. Participants and Coordination

The USACE and the MWCD have a long history of cooperation in the efficient management of the Muskingum Basin Reservoir System.   This relationship needs to continue and a combined effort by several Federal and state agencies will be necessary if revitalization of the reservoir system and solutions to other problems in the watershed are to become a reality. Recent emphasis has been placed on partnering actions by various entities in order to share the efforts and cost necessary for such a comprehensive undertaking. A major step in this effort was the formation of the Muskingum River Basin Partnering Committee in 2004, which is composed of the Federal, State and regional organizations listed below.

- Buckeye Hills Resource Conservation and Development Council
- Crossroads Resource Conservation and Development Council

- Muskingum Watershed Conservancy District
- Northeast Ohio Four County Regional Planning & Dev Organization
- Ohio Agriculture Research and Development Center
- Ohio Department of Natural Resources
- Ohio Environmental Protection Agency
- Ohio State University
- Soil & Water Conservation Districts (Ashland, Carroll, Coshocton, Harrison, Holmes, Knox, Licking, Muskingum, Richland, Stark, Tuscarawas, Washington, Wayne)
- The Nature Conservancy
- US Army Corps of Engineers
- US Department of Agriculture, Natural Resource Conservation Service
- US Department of Agriculture, Forest Service
- US Fish and Wildlife Service
- US Geological Survey

The Corps of Engineers and the MWCD have agreed to lead a major comprehensive basin study. The key component for beginning the study is attaining authorization and Federal funding as part of the Corps' General Investigation Program.

2. Muskingum River Basin

a. Economic and Social Setting

Since construction of the original flood control reservoirs in the mid 1930's, the Muskingum Basin has undergone substantial economic development and urbanization, particularly in the northern counties. The development of water resource projects has helped improve economic conditions in the basin by preventing flood damages and by increasing income from travel and tourism associated with recreation activities at the Muskingum Lakes. Since the reservoirs were completed, population in the basin has more than doubled, with the greatest growth in the northern counties of Summit, Stark and Medina. Growth in the western and northern portions of the basin has generally paralleled that of the State of Ohio, while in the southeastern portion within the fringes of Appalachia, growth and development have lagged substantially. These trends are expected to continue throughout the economic planning period which extends through 2060.

The population of the Muskingum Basin was about 1,900,000 persons in 2000. Population growth is expected to continue over the next 50 years, with the most growth in the northern counties of Summit, Medina and Stark. Likewise, family income has increased throughout the basin, allowing a growing urban population to enjoy outdoor recreation activities at many Muskingum Lakes. The interest in water-oriented activities such as boating, fishing and swimming is at an all-time high in the basin. The demand for these activities is so great at some projects that it could result in overuse and a reduction in the quality of the recreation experience. The general expectation is, however, that the Muskingum water resource projects can provide the necessary facilities to meet the increasing demand.

b. Existing Projects

The Muskingum River Basin flood control system includes 12 multiple purpose lakes and four flood control (dry) dams. These 16 projects control a drainage area of 5,060 square miles or 63% of the basin. Table 1 provides pertinent data for the projects including stream location, pool size, and flood storage capabilities. The relationships of the projects to one another are shown on Figure 1 which is a map of the Muskingum River Basin Flood Control System. The 14 original projects were jointly constructed in the 1930's by the MWCD and the Corps while Dillon Lake (1959) and North Branch of Kokosing Lake (1972) were constructed later by the Corps of Engineers. Fifteen dams are of earth fill construction while Dover Dam is a concrete gravity structure. (See Photo 1.) Each dam has an uncontrolled spillway and 12 projects have summer pools (lakes). The system provides a total flood storage capacity of 1,603,000 acre-feet. As Table 1 indicates, in addition to the Muskingum River mainstem, there are four major sub-basins in the Muskingum Basin – the Tuscarawas River Sub-basin, the Walhonding River Sub-basin, the Licking River Sub-basin and the Wills Creek Sub-basin. Each of the sub-basins is briefly described below.

Table 1. Muskingum Basin Reservoirs Pertinent Data

Name of Project	Location	Drainage Area (sq-mi)	F.C. Storage (Ac-ft)	Conservation Storage (Ac-ft)	Lake Surface (Acres)
		Tuscarawas River Sub Basin			
Dover	Mainstem	777	203,000	0	0
Bolivar	Sandy Creek	502	149,600	0	0
Leesville	McGuire Ck.	48	17,900	19,500	1,000
Atwood	Indian Fk.	70	26,100	23,600	1,540
Beach City	Sugar Ck.	300	70,000	1,700	420
Tappan	Lt. Stillwater	71	26,500	35,100	2,350
Clendening	Stillwater Ck.	70	27,500	26,500	1,800
Piedmont	Stillwater Ck.	84	31,400	33,600	2,270
		Walhonding River Sub Basin			
Mohawk	Mainstem	817	285,000	0	0
Mohicanville	Lake Fk.	269	102,000	0	0
Charles Mill	Black Fk.	216	80,600	7,400	1,350
Pleasant Hill	Clear Fk.	199	74,200	13,500	850
N.B. Kokosing	North Br.	45	13,800	3,850	150
		Licking River Sub Basin			
Dillon	Mainstem	748	260,900	32,800	2,440
		Wills Creek Sub Basin			
Wills Creek	Mainstem	723	190,000	6,000	900
Senecaville	Seneca Fk.	121	45,000	43,500	3,550

Photo 1. Dover Dam is the only concrete structure in the Muskingum Reservoir System.

- Tuscarawas River Sub-Basin

The Tuscarawas River basin located in the northeastern portion of the Muskingum basin has a drainage area of 2,596 square miles. There are eight reservoir projects in the sub-basin, three with large drainage areas and substantial flood storage capacities, and five with smaller drainage areas. (Refer to Table 1.) The smaller projects have large conservation pools which provide releases for stream flow, storage for future water supply, and relatively large lakes for recreation and fishery resources. These eight reservoirs control a drainage area of 1,922 square miles or 74% of the total drainage area of the Tuscarawas sub-basin.

- Walhonding River Sub-Basin

The Walhonding River Sub-basin, located in the northwestern portion of the Muskingum Basin, has a drainage area of 2,250 square miles. The Walhonding River joins with the Tuscarawas River at Coshocton to form the Mainstem Muskingum River, 112 stream miles above the mouth at Marietta. There are five reservoirs in the sub-basin which control a drainage area of 1,546 square miles or 69% of the total drainage area. (Refer to Table 1.) Mohawk Dam is the major flood control project, but the other four reservoirs also have flood control storage. Three of the projects have conservation pools which provide for stream flow releases and storage for potential water supply, and lakes for recreation and fishery resources.

- Licking River Sub-Basin

The Licking River Sub basin is located in the southwestern portion of the Muskingum Basin, with the Licking River entering the Muskingum River at Zanesville, Ohio. Dillon Reservoir is the only flood control project in the sub-basin, controlling 748 square miles or 96% of the Licking River sub-basin. Dillon has 261,000 acre-feet of flood control storage, and a lake of 2,445 acres which provides for recreation and fishery resources.

- Wills Creek Sub-Basin

The Wills Creek sub-basin is located in the southeastern portion of the Muskingum Basin. Wills Creek and Senecaville Reservoirs are both located within this 844 square mile sub-basin. These projects control over 99 percent of the drainage area, providing flood damage reduction along the Muskingum River. Senecaville has 43,500 acre-feet of flood storage and is a significant recreation resource for communities within the southeastern portion of the Basin. Wills Creek has even greater capability with 190,000 acre-feet of flood storage.

There also are several small projects in the Muskingum Basin that have been completed by the Corps of Engineers. These include local flood protection projects at Roseville, Massillon, Mt. Vernon, and Newark, a snagging and clearing project at Canton, and four emergency bank protection projects. Three environmental restoration projects have recently been completed in the Muskingum Basin - Linton Road in the Wills Creek Watershed, St. Louisville in the Licking River Basin, and Lick Run near Piedmont Lake in the Tuscarawas River Basin.

c. Natural Environment

The Muskingum River Basin represents a unique and diverse landscape with two distinctive geologic and topographic regions. These regions are the unglaciated and glaciated divisions of the Allegheny Plateau Physiographic Province. Nearly two million years ago fluctuations in the earth's climate led to the southern migration of glaciers as far as the Ohio and Missouri Rivers in the Midwest. These glaciers led to a vast reshaping of valleys and altering the course of rivers in the northwestern portion of the Muskingum Basin.

The unglaciated southern portion of the Muskingum Basin has peak elevations that vary from 1200 to 1300 feet with a local relief or difference between the highest and lowest elevation of 200 to 300 feet. The glaciated portion of Muskingum Basin has maximum elevations of 900 feet or less. Charles Mill, Pleasant Hill and North Branch of Kokosing Reservoirs are located within the glaciated region of the basin while the remaining thirteen reservoirs are outside the glaciated portion of the Basin. The Muskingum Basin is the largest watershed within the State of Ohio. There are twenty-six principal streams in the basin that have drainage areas larger than 150 square miles as shown in Table 2.

Table 2. Principal Streams in the Muskingum Basin

Stream Name	Length (Miles)	Drainage Area (sq. mi.)*
Muskingum River	111.9	8038
Tuscarawas River	129.9	2590
Walhonding River	23.5	2252
Mohican River	64.2	999
Wills Creek	92.2	853
Licking River	67.5	781
Killbuck Creek	81.7	613
Sandy Creek	41.3	503
Stillwater Creek	63.5	485
Kokosing River	57.2	482
Sugar Creek	45.0	356
Black Fork/Mohican	58.4	351
Lake Fork	14.7	344
Moxahala Creek	29.2	301
S. Fork Licking River	33.9	288
Conotton Creek	38.7	286
N. Fork Licking River	38.4	239
Wakatomika Creek	42.6	234
Wolf Creek	47.4	231
Clear Fork/Mohican	36.6	219
Jonathan Creek	26.1	193
Chippewa Creek	26.7	188
Nimishillen Creek	24.5	187
Salt Fork	32.0	161

Jerome Fork	24.5	159
Seneca Fork	30.3	151

The majority of the principle streams of the Muskingum Basin are located within the Mixed Mesophytic Forest Region which is coextensive with the unglaciated portion of the Allegheny Plateau. The mixed mesophytic forest of the Muskingum Basin is diverse and one of the nation's oldest formations of the deciduous forest. The dominant trees of the forest canopy often called the arboreal layer are beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*); sweet buckeye (*Aesculus octandra*); white oak (*Quercus alba*); and hemlock (*Tsuga Canadensis*). The dominant trees of the forest canopy often called the arboreal layer are beech *(Fagus grandifolia)*, sugar maple *(Acer saccharum)*; sweet buckeye *(Aesculus octandra)*; white oak *(Quercus alba)*; and hemlock *(Tsuga Canadensis)*. The most diverse areas of the mixed mesophytic forest are in the low lying regions along the rivers and streams. This area often referred to as the riparian zone, represents the middle ground between rivers and upland environments. Both density and diversity of species tend to be higher in the riparian zone than in upland areas, and the riparian zones have varying habitat features such as wetlands and oxbows. Although an important ecological component, much of the riparian zone within the Muskingum Basin is fragmented and often has been cleared of vegetation to increase agricultural production and permit the expansion of cities and towns. The restoration of the streams and riverine environments within the Muskingum Basin is important to ensure a high quality ecosystem in the future.

- Muskingum River

The Muskingum River is an important economic and ecological resource to the State of Ohio and the Nation. The Muskingum River is 111.9 miles in length and begins at the confluence of the Walhonding and Tuscarawas Rivers at Coshocton. Historically, the Muskingum River provided an effective means of transporting commodities between major markets in the East and Midwest with its series of ten locks and dams constructed in the mid 1800's by the State of Ohio. This system was abandoned for commercial use in the 1950's and is now operated only for recreational activities. The river is an important resource for sport fisherman and is known for its spotted bass and huge flathead catfish.

Ecologically, the Muskingum River is important for a variety of mussel species and the presence of four Federally Listed Threatened and Endangered mussels. These mussel species are the Purple Cat's Paw, *Epioblasm obliquata obliquata*; Fanshell Mussel, *Cyrogenia stegaria*; Clubshell Mussel, *Pleurobema clava*; and Pink Mucket, *Lampsilis abrupta*. The Federally listed Indiana Bat, *Myotis sodalist,* also is listed as an endangered species for much of the Muskingum Basin.

- Tuscarawas River

The Tuscarawas River is the largest sub-basin within the Muskingum. The river is 129.9 miles long and drains approximately 2,590 square miles. The main stem of the Tuscarawas was designated by the Ohio Environmental Protection Agency in its 2004 Integrated Water Quality Monitoring Report as having impaired habitats for aquatic life use and impaired suitability for recreation use. However, efforts are currently underway in the Upper Tuscarawas to restore the riparian zone and improve water quality. The Upper Tuscarawas watershed organization, the Northeast Ohio Four County Regional Planning and Development Organization and county governments are partnering to identify problems and opportunities to restore the Upper Tuscarawas.

- Stillwater Creek

Stillwater Creek in the southeastern portion of the Muskingum Basin is 64 miles long and drains 485 square miles. Three reservoirs, Tappan, Piedmont and Clendening, are located in the Stillwater Creek Basin. Currently, water quality in the tailwater area of Stillwater Creek is degraded because of poor water quality due to upstream mining activities. A deficiency of oxygen in the bottom layer of the lake induces chemical and biological reactions that results in the production of Hydrogen Sulfide.

- Conotton Creek

Conotton Creek is 38.7 miles in length and drains approximately 286 square miles. The area surrounding Conotton Creek has been heavily mined and acid mine drainage from abandoned mine lands is impacting the water quality of Conotton Creek. Atwood and Leesville Dams are located in the Conotton Creek Watershed.

- Walhonding River

The Walhonding River located in the Northwestern portion of the Muskingum Basin is 23.5 miles in length and drains 2,252 square miles. The Walhonding River is formed by the junction of the Kokosing and Mohican Rivers. Clear Fork and Black Fork of the Mohican River, the Mohican River, Killbuck Creek and the Kokosing River all are important tributaries of the Walhonding.

- Clear Fork of the Mohican River

Clear Fork of the Mohican River is 36.6 miles in length and a portion of the river cuts through sandstone bedrock forming the Clearfork Gorge. The gorge is more than one thousand feet mean sea level at the top and over three hundred feet deep. A section of the gorge has an old-growth white pine and hemlock community that is of national significance. The National Park Service has designated the area as a Registered National Natural Landmark.

- Black Fork of the Mohican River

The Black Fork of the Mohican River is 58.4 miles in length and flows into Charles Mill Reservoir. The Black Fork is known locally as the "Muddy Fork" because of its high sediment load which contributes to excessive sediment levels in the reservoir. Sediment at Charles Mill is severely impacting recreation resources at the lake. The MWCD recently received a grant from the State of Ohio Nature Works Program to dredge portions of the lake to provide improved boating access and to create a wetland environment from the dredged material in other portions of the lake.

- Kokosing River

The Kokosing River is 57.2 miles in length and the only State Designated Wild and Scenic River within the Muskingum Basin. The Kokosing is well known for its aquatic diversity. The diverse fish community represents one of the healthiest populations in the State of Ohio. A watershed action plan is currently being developed by the Ohio Department of Natural Resources and communities within the watershed to address ways to improve and protect water resources within the watershed, reduce non-point source pollution and protect high quality areas and existing land uses.

- Killbuck Creek

Killbuck Creek is 81.7 miles in length and a tributary of the Walhonding River. The planners of the Muskingum Projects in the 1930's at one time considered a reservoir on Killbuck Creek which would provide flood damage reduction benefits to the towns of Wooster, Millersburg and Killbuck. However, this project was never constructed and Killbuck Creek remains an uncontrolled stream. Killbuck Creek is a significant water resource to the nation due to the presence of the Purple Cat's Paw Pearly Mussel, (*Epioblasma obliquata obliquata*). Also, on lower Killbuck Creek there is a 5,490 acre marsh wildlife area managed by the State of Ohio. The Lower Killbuck Wildlife Area is the largest inland marsh outside of the Lake Erie region.

The above listed streams provide an overview of significant natural resources and existing problems and opportunities for restoration of degraded environments within the Muskingum Basin. Numerous efforts are currently underway and several Federal and state agencies are working with local communities to achieve clearly defined goals. A renewal program in the Muskingum Basin would facilitate the development of these initiatives and allow for a comprehensive approach to watershed planning.

3. Water Resource Problems

a. Aging Infrastructure

The Muskingum River Basin reservoir system is one of the oldest water resource developments in the nation. The 14 original reservoirs were jointly constructed in the 1930's by the MWCD and by the Corps. The creativity and innovation of the system's watershed planners became the benchmark for other large civil works projects across the Nation. The dams are nearly 70 years old and are twenty years past their original design lives. As would be expected with aging projects, there are structural problems, operational deficiencies, and in some instances, outdated design and construction techniques.

Some structural problems, resulting from dam seepage, were first detected at Muskingum projects more than 30 years ago. When the Corps' nationwide Dam Safety Assurance (DSA) Program was authorized in 1970, the Corps' Huntington District undertook a comprehensive evaluation program to assure that these structures would conform to current design standards. The DSA Program addresses primarily issues of hydrologic deficiency, which may involve raising the dam or widening the spillway, seismic instability, and erosion within the spillways. All other major structural problems, such as dam seepage, are considered a dam safety issue to be addressed under the Corps' Major Rehabilitation Program. DSA improvements have been completed at eight (8) Muskingum projects – Tappan, Charles Mill, Leesville, Mohicanville, Mohawk, Bolivar, Senecaville, and Beach City. The modifications have included raising height of dam with parapet walls at all eight projects, and widening the spillways at four projects. DSA measures have been designed for Piedmont and Dover, and are being planned for Clendening, Atwood, Pleasant Hill, and Dillon. The MWCD has agreed to be the non-Federal sponsor for DSA modifications at all remaining Muskingum projects.

The Huntington District was tasked in 2003 with completing a thorough review of the Muskingum Basin projects in order to identify the problems and deficiencies, determine what renovations are necessary, and prepare preliminary cost estimates for these improvements. The review was completed and the findings included in a report titled "Muskingum Basin Infrastructure Study," dated October 2005, provided in Appendix A.

The project deficiencies have been compiled from several sources. Much of the data was provided by the Huntington District Dam Safety Committee. Other sources of information include a Corps' national Screening Portfolio Risk Analysis (SPRA), project maintenance backlogs, and periodic inspection reports. The SPRA identified dam structural deficiencies, analyzed the risk associated with these deficiencies, and recommended a plan of action for addressing the risks for 60 of the Corps' riskiest dams across the nation. The improvements identified in the SPRA would require large-scale investments such as raising the dam height to reduce risk, widening the spillway and taking measures to stop dam embankment seepage at some Muskingum reservoirs. Project personnel periodically submit needs to the District office which are added to a maintenance backlog. The needs are in a database which identifies necessary improvements along with a recommended plan of action.

Finally, periodic inspections at each project identify the conditions and any deficiencies which are apparent to the inspectors. Periodic Inspection Reports are prepared once the inspection findings have been compiled, and these reports provide a valuable documentation of project deficiencies and the recommended plans of action. Included in subsequent paragraphs are brief descriptions of the major problems, operating deficiencies, and necessary renovations for individual projects. More detailed descriptions and the estimated cost of the recommended structural improvements and repairs at the Muskingum projects are provided in Appendix A of this report.

(1) Hydrologic Deficiency

The DSA program, which began in the 1970's, primarily addresses projects with hydraulic deficiencies along with seismic and spillway erodibility concerns. The Muskingum projects were evaluated under the DSA Program and only North Branch of Kokosing and Wills Creek do not require remedial measures. Hydraulic deficiencies have been corrected at eight of the projects – Tappan, Charles Mill, Mohicanville, Leesville, Mohawk, Bolivar, Senecaville, and Beach City – either by raising the height of the dam, widening the spillway or both. Design has been completed for Piedmont, which includes raising the dam with a parapet wall and providing a spillway erosion cutoff wall. Dover, the only concrete dam in the Muskingum Basin system, has a significant hydraulic problem. Under current design, the Probable Maximum Flood would top the non-overflow section of the dam by nearly 9 feet. Four other Muskingum Reservoirs - Clendening, Atwood, Pleasant Hill and Dillon are considered to be hydrologically deficient under the DSA program. These projects are scheduled for future studies to determine the appropriate remediation for the deficiency.

(2) Seepage and Foundation Problems

Several reservoir projects in the Muskingum Basin have a history of seepage through the foundation beneath the dam embankments. The seepage problems at three projects – Bolivar, Mohawk and Beach City – were evident during the major flood event in January 2005. It is considered that the dam embankment and/or foundation at these projects would become unstable due to piping at pool levels less than the spillway crest elevation. This condition could lead to piping of the embankments and threaten the integrity of the dam and possibly lead to dam failure. During the January 2005 flood event, conditions warranted emergency measures in the form of placement of filter blankets at Bolivar, Beach City and Mohawk. The failure of even one of the dams and sudden loss of pool would have catastrophic consequences to the downstream population and development, including potential loss of life. Geotechnical explorations and testing have begun at Bolivar Dam as part of a seepage correction rehabilitation study. Similar studies have been initiated at Mohawk and Beach City Dams to establish the full extent of the seepage problems. Dover Dam has a special foundation problem unlike the other projects. The concrete dam does not meet the necessary design factor of safety, and is considered unstable against sliding when the pool reaches an elevation slightly above spillway crest.

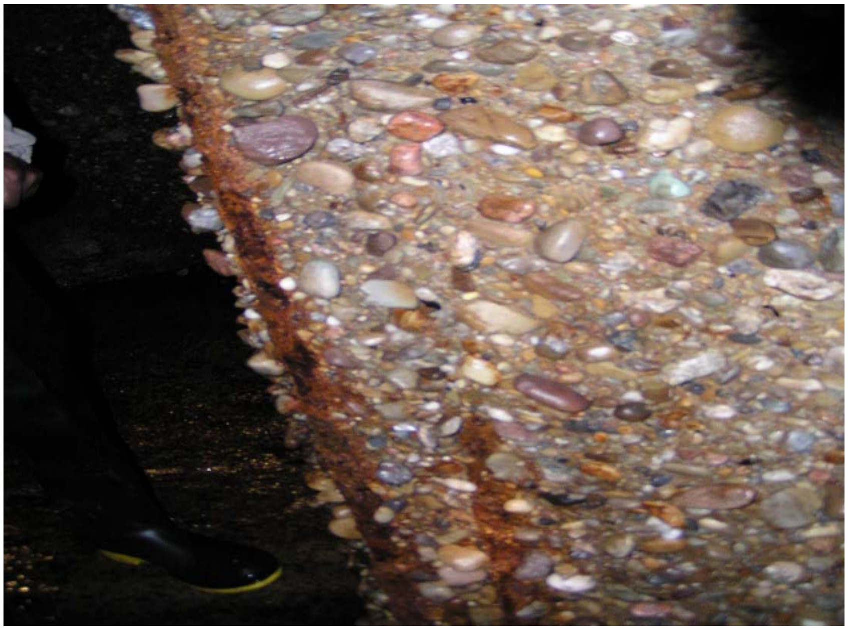
(3) Outlet Tunnel Deterioration

The presence of hydrogen sulfide at projects within the Muskingum Basin is leading to extensive deterioration of the concrete in the outlet tunnels, intake structure and related facilities. Concrete deterioration has been considered by the District as a potential dam safety problem for several years. The levels of hydrogen sulfide are high enough to cause concern for public health and safety.

In 1977, the Huntington District commissioned a study by the Corps of Engineers Waterways Experiment Station (WES) to evaluate the concrete tunnel deterioration at Piedmont and Clendening Reservoirs. Physical and chemical tests were accomplished to determine the causes of the deteriorating concrete. Chemical tests revealed that the water contained high concentrations of sulfates and sulfides, and bacteriological tests confirmed that sulfate-reducing bacteria were present. Conditions in the outlet tunnels met the criteria for the deposition and proliferation of sulfur-oxidizing bacteria which produce sulfuric acid from the hydrogen sulfide. It was concluded that infrastructure degradation of the concrete in the outlet tunnels was due to acid attack.

The concrete in many of the tunnels at projects with the hydrogen sulfide problem has eroded and deteriorated to such an extent that the concrete reinforcing steel is exposed. (See Photo 2.) The tunnel problems are most severe at Atwood, Clendening, Leesville, Piedmont, and Tappan Lakes. Analysis in 1987 indicated the tunnels could either be near the allowable stress level or highly overstressed depending on several unknown factors at the time. An instrumentation monitoring program to measure the deterioration was initiated in 1998. By using previous surveys and the instrumentation data, the amount of concrete deterioration at various locations within the tunnels is approximately 1 to 2 ¼ inches. If tunnel deterioration continues without remediation, the tunnels could collapse and result in the inability to properly release water from the lake. Emergency pumping and repair measures could be necessary to prevent potential dam failure by overtopping.

Photo 2. Outlet Tunnel deterioration at Tappan Dam due to Hydrogen Sulfide.



(4) Gate Deterioration

There are several projects within the Muskingum Basin that have structural problems associated with gates and related features. These problems are mostly due to the age of the structures and include problems with sluice gates, service gates, emergency gates and electrical/mechanical equipment such as motors and controls. The projects with the most significant gate problems are Atwood, Beach City, Bolivar, Charles Mill, Dillon, Leesville, Senacaville, Tappan and Wills Creek Lake.

The service gates at Bolivar are the most deteriorated of the Muskingum Projects. In June 2001, the Corps completed its periodic inspection of the Bolivar project and found the gates were severely corroded with significant section loss including several holes in the lower portion of the gate panels. Project personnel also indicated several functional problems with the gates at Bolivar. For instance, one of the gates would not close properly, was approximately 6 inches off the sill and therefore had a significant amount of flow beneath it. The problem could be caused by the slow movement of the gates, consequently raising and lowering the gates could correct the problem. However, the general assessment of the Bolivar gates indicated that repair or replacement would be necessary in the near future.

Photo 3. Service gate deterioration at Bolivar Dam.

Leesville is another project with extensive deterioration of the sluice gates and gate liners. In a 1993 inspection, Leesville showed problems associated with corrosion and it was recommended that the lower portion of the gate and liners be replaced. Bolivar and Leesville are examples of the numerous structural problems related to gate features in the Muskingum Basin.

(5) Spillway Erosion

Erodability of spillways is a problem at several of the Muskingum projects and is one of the deficiencies considered under the DSA program. Erosion of the unlined portions of spillways is of the most concern at Piedmont, Pleasant Hill and Tappan. An erodability analysis for Piedmont Dam indicated that the spillway foundation consists of fractured claystone which is susceptible to headcut erosion. Further, that during a rare flood event (75% Probable Maximum Flood) the unpaved portion of the spillway would erode breaching the paved spillway crest. This occurrence could cause the loss of the reservoir pool and result in significant destruction downstream of the dam. Plans to correct this deficiency include the construction of a 30-foot wide concrete cutoff wall down to bedrock at the downstream end of the spillway crest. Erodable rock in the unlined portions of the spillway is the major concern at both Pleasant Hill and Tappan. Geotechnical studies have been recommended for each of these projects to determine the extent of the problem and potential remedial work required.

(6) Relief Wells

All dams with impounded pools have some degree of under seepage. Seepage can emerge on the downstream face of the dam or anywhere at elevations below normal pool due to hydrostatic pressure of impounded water. Relief wells provide a means to reduce the pressure that could potentially threaten the stability of the dams. Relief wells have been installed at most projects within the Muskingum Basin. However, from data in the Periodic Inspection Program it has been determined that the relief wells are becoming plugged due to iron and sulfate reducing bacteria. Due to funding constraints the last major maintenance on any of the relief wells was conducted in 1994.

The January 2005 flood highlighted concerns on the severity of under seepage at several projects within the Muskingum. Clendening, Dillon, Leesville, Piedmont, Senacaville, Tappan and Wills Creek also have significant concerns with dam seepage and the functionality of relief wells. Seepage was such a concern at Beach City, Mohawk and Bolivar during the 2005 flood event that emergency filter blankets were installed at areas where sand boils developed through the foundation beneath the dam embankment. (See Photo 4.) The filter blankets were installed as a temporary emergency procedure.

Photo 4. Sand Boil at Beach City Dam.

(7) Appurtenant Facilities

Structural deficiencies in the Muskingum Basin occur not only at the reservoir projects but also at appurtenant facilities such as levees and dikes. Zoar Levee in the Dover pool is an example of an appurtenant facility that has structural problems. This levee which protects the historic town of Zoar, Ohio, does not meet current hydrological design criteria. If a Probable Maximum Flood should occur, the levee embankment would be overtopped by approximately 12 feet of water, resulting in catastrophic damages in the town. During the January 2005 flood, sand boils developed inside the levee requiring emergency repairs similar to those at Bolivar Dam and Beach City Dam. There also was seepage at the Pavonia Levee in the Charles Mill pool. The seepage at that project was determined to be in an area where a utility line crosses the levee embankment, and was controlled before becoming a serious problem.

b. Reservoirs

(1) Reservoir Operations

Current operational problems at reservoirs have developed progressively over the life of the projects, spanning nearly 70 years. Most are the result of changes throughout the basin as well as conflicting water resource demands which often are beyond the scope of normal project operations. Examples include increased development in the floodplains downstream of projects, and acid mine discharges which enter streams in the upper watersheds and subsequently may impact lake quality.

At several projects in recent years, stored floodwaters in reservoirs have not always been released in accordance with the original flow or stage targets. Encroachments resulting from extensive land use development in downstream reaches have affected the operational capacity of the floodway. For small flood events, a reduction in target flows minimizes complaints from owners with minor property damage while having little overall impact on project operations. However, during major events such as the January 2005 flood, reduction in target flows has the effect of reducing available flood storage capacity throughout the reservoir system.

Downstream flow rates for floodwater releases have been modified for the above reasons at several of the Muskingum reservoirs, but greatest restrictions have been imposed in the Tuscarawas and Walhonding sub-basins. This has been necessary because of the presence of eight reservoirs in the sub-basins, each with a need for efficient release of flood storage. Five of the projects are upstream of the highly developed Dover/New Philadelphia area. The current situation can affect the capability of the reservoir system to effectively store flood waters and reduce potential damages downstream. Target flow rates have been reduced the most at Charles Mill, Dover, and Mohawk Lakes. This highlights the need to discharge water from Bolivar as quickly as possible to avoid structural instability impacts.

(2) Sedimentation and Flood Storage Loss

Sedimentation can adversely affect reservoirs in several ways - reduction in flood storage, diminished lake area for boating, boat ramps and beaches, reduction of available storage for downstream flow releases or water supply withdrawals, and degradation of water quality in the lakes. Reduction in flood storage currently is not regarded as a significant problem; however, some reservoirs such as Beach City and Wills Creek have lost nearly their entire conservation pools and further reductions in flood storage are anticipated. Within the forecast period of 50 years, sedimentation will have a more pronounced effect at other projects such as Dillon and Charles Mill. Table 3 shows the reduction in storage at several Muskingum reservoirs due to sedimentation.

Table 3. Changes in Conservation Storage Due to Sedimentation.

Project	Survey Date	Original Conservation Storage (ac-ft)	Estimated Sediment Volume (ac-ft)	Storage Reduction
Atwood	1999	24,250	3,230	13%
Beach City	1993	1,700	1,700	100%
Bolivar*	-	-	-	-
Charles Mill	1998	7,330	1,870	26%
Clendening	2004	26,500	Data Not Available	-
Dillon	1998	17,000	6,400	38%
Dover*	-	-	-	-
Leesville	2001	20,000	2,540	13%
Mohawk*	-	-	-	-
Mohicanville*	-	-	-	-
North Branch Kokosing	2003	930	220	24%
Piedmont	1998	36,920	7,540	20%
Pleasant Hill	1998	14,400	3,570	25%
Senecaville	1998	44,500	10,100	23%
Tappan	1998	35,840	6,900	19%
Wills Creek	2002	5,700	4,580	80%

* Bolivar, Dover, Mohawk and Mohicanville are dry dams and do not have conservation pools.

Impacts of sedimentation on recreation use and facilities have had the most dramatic effect at the project lakes. Available lake areas for fishing and boating opportunities have been reduced where sections of the lake have become too shallow to navigate. Some recreation facilities are no longer usable because of the sediment deposition at lakes such as Dillon, Charles Mill, and Beach City. Although always a project purpose, recreation activities have proven to be much more successful than originally anticipated and individuals who benefit from flood control and those that benefit from lake recreation often have opposing views.

Massive amounts of sedimentation in the Muskingum Lakes have also contributed to degraded water quality, including a reduction in the diversity and density of fish species. High suspended sediments and organic nutrient loads in the lakes lower the dissolved oxygen levels and reduce both the number and quantity of intolerant aquatic organisms. Sediments cover and smother fish eggs and macroinvertabrates, interfere with respiration in gilled organisms, and degrade suitable habitat for fish and other aquatic species. Increased turbidity and warmer temperatures also can lead to a reduction in the aquatic ecosystem, especially insects, which create a negative impact throughout the food chain.

(3) Lake Quality

Water quality was not a major concern when the Muskingum Reservoirs were constructed in the 1930's. Consequently, no means for controlling water quality, such as the ability to selectively withdraw water from different levels of the reservoirs, were incorporated in the design of the projects. If the Muskingum projects were constructed today, each project would have selective withdrawal which allows for the release of water from different depths in the lakes.

Thermal Stratification results in layers with different physical, chemical and biological characteristics. The top lake layer has relatively high levels of dissolved oxygen (DO) while the bottom layer may be void of DO due to various oxygen-demanding materials and processes. Consequently, water released from lake bottoms during the stratification season (April through September) may be low in DO and high in metals.

Due somewhat to changing land uses, such as mining in the upper parts of the watershed, inflow to some lakes includes high concentrations of chemicals such as manganese and sulfate. During the summer stratification season when the bottom of the lake is anoxic, manganese levels often increase and hydrogen sulfide is formed. Releasing storage from the bottom of the lake, as is the only current alternative, creates conditions which allow for release of hydrogen sulfide (H_2S) gas in the tailwater areas. The H_2S problem is most prevalent at Atwood, Clendening, Leesville, Piedmont, and Tappan Lakes.

Point source and non-point source pollution also affect the water quality of the lakes. Point source refers to a localized pollutant source, such as a particular industry or pipeline, while non-point source refers to pollutants that indirectly contaminate waterways, such as runoff from agricultural fields, or urban areas. Non-point pollution sources cause significant contamination, but it is difficult to control because it is not localized. The MWCD, ODNR, OEPA and other state and local agencies invest a great deal of resources to limit both point and non-point source pollution.

(4) Conflicts Among Project Purposes

Conflicts may arise when operating the reservoirs for the various project purposes. For example, delayed releases of flood storage because of downstream flow restrictions may impact recreational use of the lakes. Following a flood event, recreational users may find facilities inundated. If use of the lakes for water supply increases in the future, then lake conditions favorable for recreation use could be affected by increased water withdrawals. Additional withdrawals would only increase the present shallow areas in the lakes and may curtail the uses of the reservoirs for boating and fishing. Extensive modeling of the reservoir system will need to be conducted to determine the optimum storage/release schedule.

c. Watershed Problems

(1) Ecosystem Degradation

Significant changes affecting the Muskingum Basin's water resources have occurred since the original reservoirs were constructed in the 1930's. Land use patterns and practices have changed greatly and, in some instances, have limited the ability of rivers and streams to perform critical ecological functions. Land uses, such as residential and commercial development, certain agricultural practices, and mining contribute to accelerated erosion and increased sediment deposition in the lakes and streams. Mining activities have led to significant aquatic degradation from acid mine drainage. Agriculture activities such as crop cultivation and raising livestock result in significant loss of vegetation, increase overland (sheet) erosion, and general livestock pollutants which may enter the waterways. Consequently, in the streams and eventually the lakes, there is increased turbidity, reduced light penetration, and reduction in water depths. Sediment accumulation in the lakes has accelerated eutrophication, reduced deep water habitat, impacted benthic populations (especially spawning and rearing habitat) increased suspended solids and turbidity, and decreased water depths which facilitates summer thermal effects. Erosion of unstable stream banks and channels is the source of much of the sediment which enters the lakes. Some lakes such as Beach City have been so impacted by sediment accumulation that much of the conservation pools are exposed unvegetated mud flats in the summer.

Residential and commercial developments in many watersheds have increased the amount of impervious surface, which in turn reduces the infiltration potential of the lands, decreases groundwater recharge, and thereby increases the total volume of runoff which reaches the rivers and streams. This occurrence can become so pronounced that it affects the frequency and duration of bankfull events, which lead to stream disequilibrium, channel and bank instability and increased sediment transport. The ecosystem degradation problem in the Muskingum Basin can be broadly classified as stream instability, erosion, increased sedimentation, riparian zone degradation and acid mine drainage.

(2) Acid Mine Drainage

Acid Mine Drainage (AMD) is any discharge which contains acidity, iron, manganese, aluminum, and other metals. AMD is formed when certain sulfur minerals in coal and bedrock are exposed to oxidizing conditions. This process can occur naturally if rock containing iron-pyrite coal is exposed through weathering, but most significant acid drainage problems result from mining operations. AMD can vary from high-flow perennial discharge to sporadic seasonal seeps.

AMD primarily from underground mines along Moxahala Creek, Brush Creek and Black Fork have resulted in significant degradation of these streams. Moxahala Creek, which enters the Muskingum Basin downstream of Zanesville, is an example of a particularly severe AMD problem. Although acid flow from Moxahala Creek does not directly impact any MWCD lakes, it does affect the water quality of the lower Muskingum River Mainstem. The Soil Conservation Service (now the Natural Resource Conservation Service) in a 1985 report titled "Areas in Ohio Impacted by Abandoned Mines," indicated that the watersheds of Moxahala Creek, Upper Stillwater Creek, Sugar Creek, and Wills Creek had the most severe AMD problems. Over 185 abandoned mined lands (AML) sites have been identified upstream of the Muskingum Lakes and the estimated cost to remediate these sites is $234 million. Table 4 presents the number of surface and underground AML sites located above the Muskingum Lakes by county.

(3) Residual Flood Damages

Residual flood damages are significant in the Muskingum Basin even though there are 16 reservoirs and 4 local flood protection projects. Currently, basin-wide average annual flood damages are estimated to be $40 million, with approximately $6 million occurring in the watershed upstream of the reservoirs, and approximately $34 million occurring in the floodplain downstream of the projects. These high residual damages are the result of increased use of floodplain lands over the past 70 years, plus higher-value damageable property both upstream and downstream of the reservoirs. Much of the floodplain development occurred before creation of the National Flood Insurance Program (NFIP) in 1968. Beginning in 1975, counties in the Muskingum Basin began entering the NFIP, which resulted in a decline of development in flood hazard areas.

Table 4. Surface and Underground Abandoned Mined Land Sites Located Above the Muskingum Lakes.

Project	Number of Surface AML Sites	Number of Underground AML Sites	Total
Atwood	0	6	6
Beach City	0	25	25
Bolivar	4	32	36
Charles Mill	0	0	0
Clendening	0	3	3
Dillon	1	2	3
Dover	7	37	44
Leesville	0	1	1
Mohawk	0	0	0
Mohicanville	0	0	0
North Branch Kokosing	0	0	0
Piedmont	5	2	7
Pleasant Hill	0	0	0
Senecaville	4	16	20
Tappan	9	7	16
Wills Creek	4	24	28
TOTALS	**34**	**155**	**189**

Source: ODNR, Division of Mineral Resources Management.

There are locations throughout the basin where significant flood damage occurs, and where prior studies have been conducted in an effort to reduce the potential for future flooding. Several damage centers are described below:

- Mansfield, Ohio is inundated by Clear Fork and Black Fork of the Mohican River. A local protection project was authorized at Mansfield in 1986 but was never constructed.

- Canton, Ohio receives flood damages from the overflow of East and Middle Branches of Nimishillen Creek, a tributary of the Tuscarawas River. A channel improvement project has been investigated but not constructed at Canton.

- Crooksville Village, Ohio is flooded by the overflow of Moxahala Creek about 15 miles above the confluence with the Muskingum River. A channel improvement project at Crooksville was unfeasible; however, considerable economic growth in the area may warrant a re-evaluation of the project

- Loudonville, Ohio is inundated by the Black Fork of the Mohican River, about 2.5 miles above the confluence with the Mohican River.

- Killbuck Village, Ohio frequently receives overbank flooding from Killbuck Creek and the July 1969 Flood was very damaging along Killbuck Creek. A local protection project (levee) at Killbuck Village was authorized in 1986 but never constructed.

- Millersburg, Ohio, located about 5 miles upstream from Killbuck Village, also is damaged by flooding from Killbuck Creek and needs to be investigated.

- Cambridge, Ohio is inundated by overbank flooding from Wills Creek and Leatherwood Creek. Cambridge and Guernsey County both were heavily damaged by flooding in 1998. A local protection project (levee) which has been investigated at Cambridge is marginally feasible. A re-evaluation of this project may be warranted.

The January 2005 Flood was the result of 8-10 inches of rainfall over the Muskingum Basin. This was compounded by a snowfall of 2-5" in late December, which melted during January 2005 which was the wettest January on record for Ohio. Tuscarawas County, in the Northeast portion of the basin, had about 7 inches of rain. The heaviest rainfall, totaling nearly 10 inches, occurred along the Upper Licking River and the Walhonding River upstream from Mohawk Dam. Rainfall totals for first half of January at some representative projects were: Wills Creek – 7.2 inches, Mohawk – 8.4 inches, Charles Mill - 6.7 inches, and Dillon – 8.5 inches.

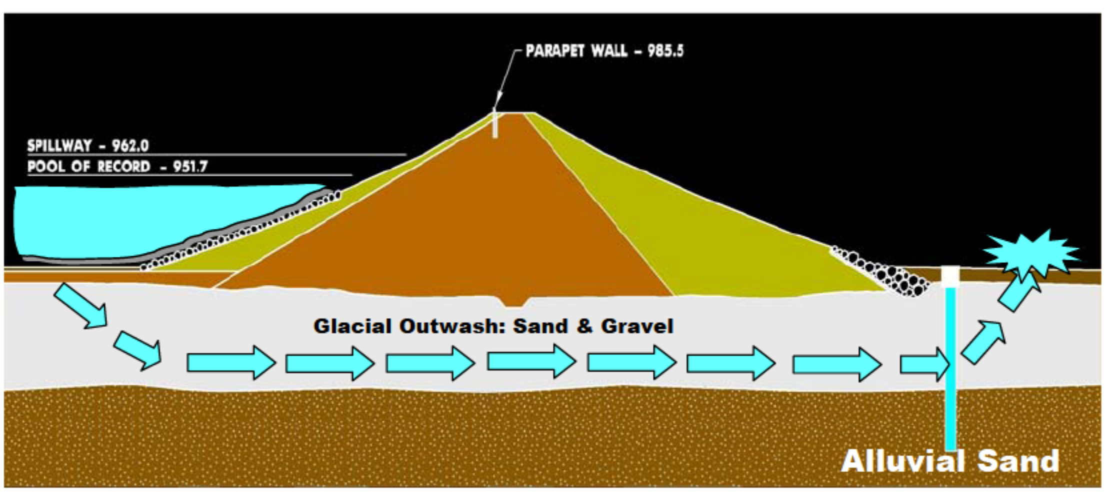
Seven reservoirs in the Muskingum Basin – Atwood, Bolivar, Charles Mill, Dillon, Dover, Mohawk and Wills Creek - reached record pool levels and Beach City nearly reached its record pool in January 2005. (See Photo 5.) The Wills Creek pool exceeded spillway elevation and for the first time a Muskingum reservoir spillway was used, and Charles Mill and Dillon Reservoirs were within 3 feet of spillway elevation. There were dramatic increases in pool levels, (i.e., Dover pool increased 30 feet in 17 days and Wills Creek over 34 feet in 14 days). Wills Creek Reservoir exceeded 100% of its storage capacity, while Dillon and Charles Mill used 93% and 80% of available storage, respectively. A report detailing more specifics on the January 2005 Flood is at Appendix B.

During floods the reservoirs are expected to maintain control stages at certain downstream locations. In early January 2005, the Muskingum Reservoirs were operated to retain floodwaters in order to minimize the discharge into the Ohio River which was already at flood stage. Major control locations in the basin include New Philadelphia, Uhrichsville, and Newcomerstown on the Tuscarawas River, Loudonville and Warsaw on the Walhonding River, and Coshocton, Zanesville and McConnellsville on the Muskingum Mainstem, and Marietta on the Ohio River. The reservoirs were effective in reducing flood stages at many locations such at Urichsville – 10.5 feet, New Philadelphia – 4.5 feet, Coshocton – 9.3 feet, and Marietta – 9.5 feet. The total flood damages prevented during January because of the Muskingum Reservoirs were estimated to be $418 million. For a breakdown of flood damages prevented for each Muskingum Project see the Scioto and Muskingum Area January 2005 Flood Event Recap Report at Appendix B.

Photo 5. January 2005 - Pool of Record for Bolivar Dam (right). The Dover pool reached pool of record as well and backed up to the base of Bolivar Dam. (left).

Bolivar is normally a dry reservoir impounding water only during flood events. When record pool levels were reached at Bolivar in January 2005 there was seepage through the terrace embankment area, resulting from seepage through the dam foundation. (See Figure 3.)

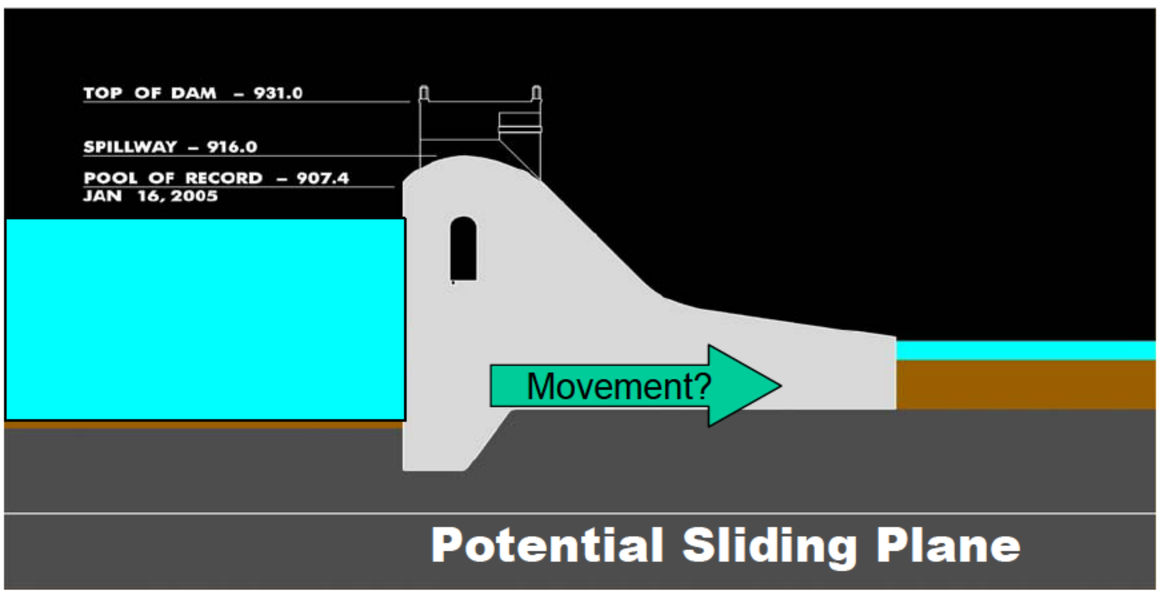
Figure 3. Seepage through foundation at Bolivar Dam.



Bolivar is the project with the greatest safety concerns in the District, primarily because of a seepage problem under its embankment. The seepage under the dam was partially controlled by the placement of an additional filter blanket, but the deterioration of the outlet works has not been repaired. Similar seepage problems were experienced at nearby Beach City Reservoir. Boils developed downstream of the embankment which required sandbags, and an emergency filter blanket had to be constructed. In addition, the relief well system did not properly handle the seepage problem.

Dover Dam, located upstream from New Philadelphia, also achieved a pool of record during the January 2005 Flood. A number of structural deficiencies have been observed at Dover since 1970, the most significant of which is sliding instability due to weakness within the foundation hardrock. (See Figure 4.) Also, the spillway is inadequate to pass the Probable Maximum Flood.

Figure 4. Potential sliding instability at Dover Dam.



Dillon Reservoir reached record levels during January 2005 and the pool was within 2 feet of spillway elevation. During this flood, some seepage was observed through the embankment at the downstream face of the dam along the concrete drainage ditch, but did not result in any major problems. The access road across the dam which is a state highway had considerable damage due to the heavy traffic use that occurred because several local roads were inundated by the high pool.

When Muskingum reservoirs stored flood waters and reached record pool levels, roads and other facilities were inundated in the reservoir pools. (See Photo 6.) In the Dover pool for instance, Ohio 212 was closed for 19 days along with several county roads, including the Dover-Zoar Road (County Route 82). The communities of Zoar, Mineral City, Yorkshire Zoarville, and Wiltshire Hills were isolated for several days and the county school system was closed 12 days due to impounded flood water. Even the access road to Bolivar Dam was closed by high water and the project isolated for a short time. In total, about 6,500 residents of Tuscarawas County were affected by record pools at Dover, Bolivar and Beach City reservoirs. Highways also were inundated in the Dillon Pool, Muskingum County, and a secondary road in the Atwood pool, Carroll County.

Photo 6. During the January flood event many roads, like Route 60 above Dillon Dam shown here, were inundated as the pools rose to record heights. Although within the flowage easements, the record high pools caused many residents to be trapped in their homes because roads were underwater.

In an effort to lower the reservoir pools and restore highway access as soon as possible, releases from reservoirs became a critical issue. During the January 2005 flood, releases were made in accordance with the originally established downstream control stages, with a few exceptions where dam safety was an issue. Over the past 20-30 years, control stages have been lowered at some locations to protect development which has occurred in the floodplains below the 100-year flood level, however, control stages were not lowered in January 2005. At a few locations, such as below Dover Dam near New Philadelphia and at Zanesville on the mainstem Muskingum River, several homes which are located in the floodplain were damaged by reservoir releases. However, only a few structures were seriously affected and these are located below the 100 year flood level.

In addition to structural problems at dams, there were other problems at appurtenant facilities, particularly levees. For example, at Zoar Levee in the Dover pool there were problems where sand boils were observed along the inside of the embankment. Seepage also was detected at the Pavonia Levee in the Charles Mill pool. The seepage was related to a utility line crossing the levee and did not present a significant problem.

Another concern during the flood was in regard to flood easements. It was noted at Wills Creek that if the pool got much higher than spillway crest, some damages could occur to structures upstream from the dam and flood easements have not been acquired above spillway elevation. Apparently, this is true for all of the original 14 Muskingum reservoir projects, and conceivably could leave the Corps and the MWCD open to potential litigation if the spillway crest is exceeded.

(4) Floodplain Development

Floodplains directly provide for the storage of floodwaters that can help reduce peak flows and the frequency of flooding downstream, and alleviate some of the flood storage pressures at the reservoirs. Additionally, floodplains increase the potential for groundwater recharge, which can reduce runoff volume, and provide significant water quality and ecological benefit.

Active floodplains, that is, floodplains at or below the bankfull stage, are a significant key for maintaining naturally stable, healthy streams. And within the Muskingum Basin the valley types are generally broad so that wide floodplains are naturally occurring in much of the basin and extend well into the headwaters. Generally, the wider the active floodplain the more stable streams become and the higher the water quality within the streams. A wide floodplain provides lateral space for a stream or river to meander and adjust its length to changing watershed or climatic conditions and helps maintain low shear stresses within the channel so that stream adjustments are gradual. A stream system that is provided the lateral space to adjust will maintain the habitat (i.e. steeper riffles, deeper pools, diverse flow hydraulics) necessary to support a rich population of macroinvertebrates and fish, which is key to achieving water quality standards. Also, floodplains that have a significant interaction with the stream (e.g. annual flooding) can provide diverse terrestrial habitat.

Studies have shown that meandering streams with active floodplains store 30 to 50% of the annual sediment load (D.E. Walling, 1999). This amount of sediment storage could provide significant reductions in the annual sediment load entering the flood control reservoirs in the Muskingum Basin. Additional benefits of depositing sediment on the floodplains are that nutrients and other chemical pollutants are generally attached to these particles. Removing silts and clays improves the water quality, since nutrients and other attached pollutants are also removed from the stream. This reduces the chemical oxygen demand on the stream and can preserve aquatic species.

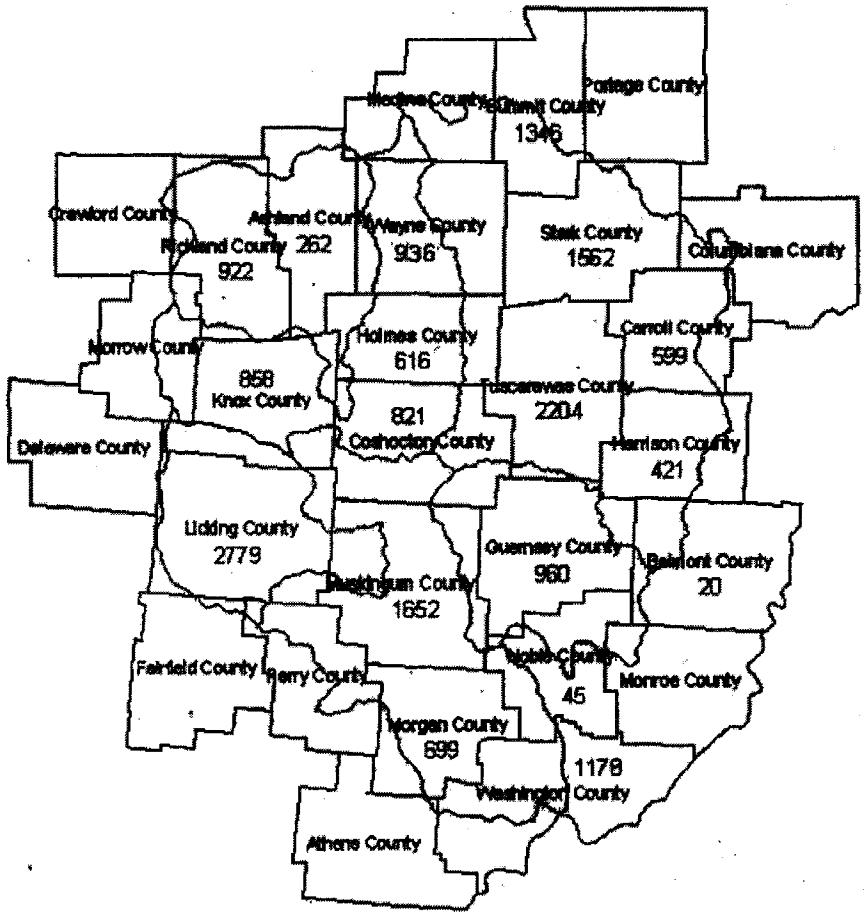
Significant development has occurred within the floodplains along protected reaches downstream of the Muskingum reservoirs. This development has occurred since the projects were constructed on floodplain lands below the 100-year flood, which can be damaged by reservoir releases. Downstream development has substantially increased operational problems for individual reservoirs projects and if releases are modified it could reduce the overall effectiveness of the flood control system.

Almost all of the development in the floodplain occurred before the initiation of the National Flood Insurance Program (NFIP) in 1968. Before the creation of this program, the only floodplain management accomplished was through regulation by state and local governments. Prior to the NFIP, the public could not readily purchase flood insurance for residences, and other non-structural means of reducing flood damages often were overlooked. Since 1975, all counties within the Muskingum basin and about 140 municipalities have participated in the NFIP. Under the provisions of this program, a participating county or community must adopt a local ordinance to meet at least minimum floodplain management requirements and use floodplain maps prepared by FEMA for planning and regulating development in the floodplain. In return, FEMA makes Federal flood insurance available to residents of the participating county. Nearly 18,000 structures are located in the floodplain in the Muskingum Basin. These structures value approximately $1.8 billion and with a risk of 1 percent equate to $17 million at risk per year. Table 5 lists the structures in the floodplain by county in tabular form and Figure 5 shows the number of structures in the floodplain in each county within the basin.

Table 5. Structures in the Floodplain by County.

County	**Number of Structures in the Floodplain**
Ashland	262
Belmont	20
Carroll	599
Coshocton	821
Guernsey	960
Harrison	421
Holmes	616
Knox	858
Licking	2,779
Morgan	699
Muskingum	1,652
Noble	45
Richland	922
Stark	1,562
Summit	1,346
Tuscarawas	2,204
Washington	1,178
Wayne	936
TOTALS	**17,880**

Figure 5. Structures in the Floodplain in the Muskingum Basin.



While the NFIP together with local zoning ordinances have reduced the growth in floodplains, a risk of flooding still remains in some area of the Muskingum Basin. The risk can be attributed in large measure to the following:

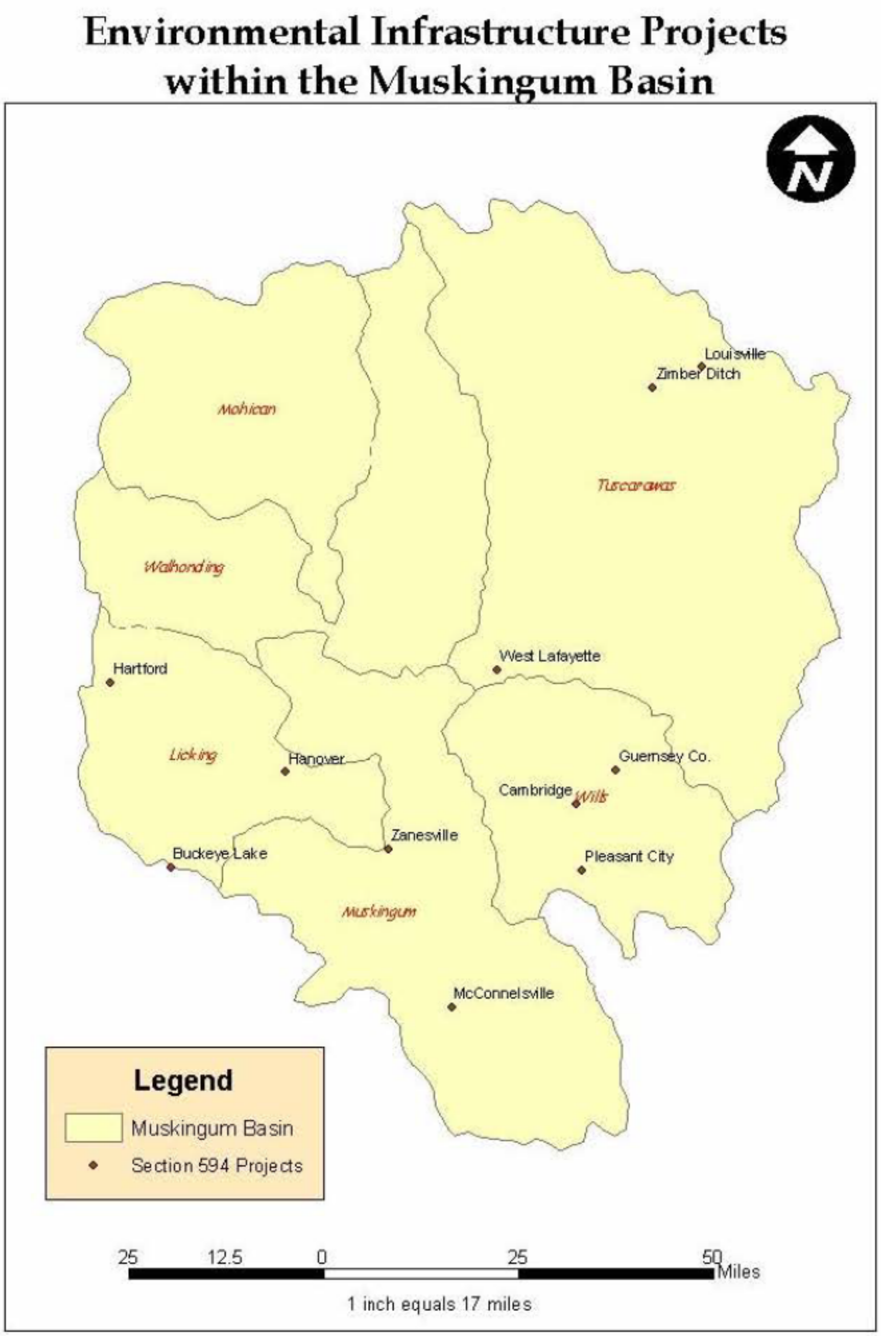
- Encroachment in the floodplains which, in some cases, is exacerbated by the limitations of NFIP and state and local floodplain management regulations;
- Outdated and often inadequate floodplain maps resulting from inaccurate stream hydrology and channel geometry;
- Insufficient funds for flood proofing and/or relocation of repetitively damaged structures.

Given the importance of floodplains, steps need to be taken to preserve floodplains, restore active floodplains, develop buffers zones (discussed in the Study), and improve local floodplain regulations to limit floodplain encroachment significantly beyond the National Flood Insurance Program (NFIP) minimum standards. Floodplain regulations under the NFIP focus on flood damage reduction, but floodplain regulations also need to focus on the function of floodplains in regards to maintaining channel stability, providing flood storage volume, improving water quality and ecological benefits. The effort to preserve and restore floodplains will not be something easily accomplished and it will take the combined efforts of federal, state, and local governments working in concert to change our historic direction of loosing active floodplain.

(5) Water and Sewer Infrastructure Needs

Inadequate water and sewer line infrastructure is another major watershed problem that can be addressed under a comprehensive rebuilding program for the Muskingum Basin. Several hundred sites within the Muskingum Basin have been identified by the Ohio Environmental Protection Agency and other agencies that have a need for modernization of basic water and sewer services. Appendix C contains a list of the sites with environmental infrastructure needs in the basin. The problem and needs range from renovation of water and sewage treatment plants to the installation of water and sewer lines. The infrastructure problems are the greatest in the Tuscarawas sub-basin with approximately 80 communities identified with needs, and in the Walhonding sub-basin with nearly 50 communities having inadequate water and sewer facilities. The Corps currently has a program to address infrastructure needs in Ohio under authority of Section 594 of the 1999 Water Resources Development Act. Eleven projects are now underway for the several hundred problem areas identified and these eleven projects are shown on Figure 6.

Figure 6. Map of 11 Active Section 594 Projects within the Muskingum Basin.



4. Plan Formulation

a. Summary of Problems and Changed Conditions

(1) Economic Growth

Most economic growth has occurred in the western and northern portions of the basin, paralleling that of the state. The southeastern portion of the basin generally has lagged that of the state and the nation, and these trends are expected to continue for the next 50 years. Water resource development in the Muskingum Basin is partially responsible for the growth in some areas.

(2) Land Use Changes Related to Water Resources

Farming is very important and accounts for about 60% of the basin land use. Agriculture activities often produce soil erosion, both surface or sheet erosion, and stream bank erosion. Erosion results in the loss of valuable soil necessary for agricultural productivity, and increases the sediment loads in the rivers and streams.

Coal production has been a significant industry in eight of the southern-most counties over the last 25-30 years. Much of the coal mining during this period was conducted by surface mining methods and the mined areas, as well as deep mines, continue to cause water quality problems in rivers and streams. Acid mine drainage from the high sulfur content and concentration of other minerals within coal bearing strata, has become a major cause of water quality problems. Urban development and surface mining also contribute to sedimentation problems in streams and lakes.

Structural development has occurred in the floodways downstream of several of the reservoirs. This encroachment in areas that originally were set aside for reservoir flood releases has resulted in the reduction of flows (and stages) at several projects because of complaints from property owners. This deviation from flow targets has previously effected the operations of several flood control projects, and was particularly evident at Dover and Bolivar during the January 2005 flood.

(3) Environmental Considerations

During the 70 years since the reservoirs were completed, there has been a general reduction in the quality of the natural environment within the Muskingum Basin. This situation includes the degradation of water quality and the loss of wetlands. Acid mine drainage has become a significant problem along certain tributaries as a result of coal mining operations. Moxahala Creek, a tributary which enters the Muskingum River near Zanesville, is a particularly severe example. Other streams with similar water quality problems are Wills Creek above the reservoir, Lick Run near Piedmont Lake, and Huff Run near Bolivar Dam. Several Section 1135 and Section 206 studies are underway which include remedial actions for acid mine drainage.

Poor land use practices in the watersheds have increased sediment discharges to streams and reservoirs. Sediment accumulation in reservoirs has accelerated eutrophication, reduced deep water habitat, increased turbidity, impacted spawning habitat and decreased light penetration. Some reservoirs like Beach City, Charles Mill, and Dillon have received so much sedimentation that major portions of the lakes become un-vegetated mudflats during the summer.

Releases are made from the Muskingum Reservoirs primarily for the purpose of augmenting flows during periods of naturally occurring low flow. The benefits of augmenting flow are related to improved water quality and aquatic habitat. During the design phase, water quality of the release was not a concern. Thus, the initial design did not provide a means to regulate releases for water quality. Inflow to many of the lakes include concentrations of minerals and much of these minerals attach to sediments and settle to the bottom of the lakes. Consequently, water released from the lake bottoms is of poor quality, demonstrating the need for multi-level discharge capabilities. Bottom releases also create the conditions which allow for the release of hydrogen sulfide gas in the tail water areas.

(4) Recreation Demand

Recreation use at the Muskingum Lakes has been substantially more successful than originally envisioned. The large urban population in the northern counties of the basin, together with increasing family income, has resulted in accelerated demand for lake-oriented recreation. Water-based activities and facilities have proved to be great attractions. There is an upward trend for boating, fishing, and camping as more users seek opportunities for outdoor recreation. There is pressure on the MWCD to satisfy the increasing demand for water-based recreation, while controlling overuse to minimize environmental degradation.

There continues to be strong interest in fish and wildlife activities, particularly hunting and fishing, at the Muskingum Lakes. The general expectations are that the MWCD projects can provide additional resources to meet this demand, while at the same time conserving valuable fish and wildlife resources. The Ohio Department of Natural Resources is a cooperative partner with the Corps and the MWCD and will continue to provide professional planning for fish and wildlife management purposes.

(5) Recreation Capability

Extensive recreation facilities are available at ten of the Muskingum Lakes with conservation pools. These lakes vary in size from 420 acres to 3350 acres with a combined total water surface area of about 16,000 acres. Facilities vary considerably among the projects, from resort-type facilities with a lodge at Atwood Lake, to more traditional lake facilities at other projects. Eight of the lakes have marinas, five have year-round camping and swimming beaches, and overnight accommodations of various types are available at eight of the lakes. Along the Mohican River near Londonville there is a substantial downstream canoeing industry that is very popular with the public. The majority of the lands at the MWCD projects are available to the public without fee for activities such as fishing, hunting and hiking. Even with extensive recreation facilities at most of the lakes, the demand far exceeds the available facilities. For example, Atwood and Tappan Lakes need additional campsites; Senecaville and Charles Mill Lakes need vacation cabins; and additional boat launching ramps are needed at several projects in order to meet the current demand.

Several of the MWCD reservoirs extensively used for recreation are located in sub-basins that have experienced significant sedimentation problems. Available water areas for boating and fishing have been reduced as significant portions of the lakes have become too shallow to navigate. Drawdown of conservation storage to provide downstream flow releases or for future water supply withdrawals would further aggravate the problems as the areas of shallow water are expanded. The impacts of sedimentation are most severe at Beach City, Charles Mill, Dillon and Wills Creek Lakes. Boating already has been limited at some projects such as Charles Mill and Beach City and over the next 50 years the sedimentation problems could curtail water-oriented recreation entirely at some projects.

(6) Flood Control Management

During the early years of operating the reservoirs for flood damage reduction, it was determined that limited stream channel capacity downstream of certain reservoirs affected the timely release of flood storage. In later years, encroachments along downstream reaches have further reduced the operational flow capacity of the floodway due primarily to property owners who could be affected if downstream flow targets are met. Deviations from flow targets are important since this action reduces the capability to achieve effective flood damage reduction during large flood events.

The Corps of Engineers and the MWCD own or control nearly 190,000 acres of land at the original 14 projects, 135,000 acres of which is flowage easement in the flood control pools above the dams. Some habitable structures were allowed to remain in the flowage easement lands in the upper reaches of the reservoir where the risk of inundation was not great. Reservoir easement lands for flood control also were not always marked to identify the maximum limits of the flood storage. Since very large flood events have been rare (Wills Creek was the first Muskingum project to use its spillway in January 2005) the easement lands which legally are usable for agricultural purposes were often developed by land owners for residential purpose in violation of easement restrictions. Because of potential impacts on flood control operations, measures were undertaken in the 1970s to address the flowage easement problems. More than 500 habitable structures with first floors below spillway design elevation have been identified. A policy was established which allowed three-fourths of these structures that are near spillway elevation to remain, where the risk of inundation is slight. Most of the remaining structures have been removed, and efforts are being made to curtail any new development in the reservoir flood control pools. There is no appreciable loss of effective flood control storage because of the structures that have been allowed to remain.

Sedimentation has accumulated in the reservoirs in varying amounts in both conservation and flood storage pools. Sedimentation has reduced the conservation pools (summer pools) at several reservoirs, and has totally eliminated the conservation pool at Beach City Lake, but has not significantly impacted flood storage, except for the headwaters of Dillon Lake. However, in the next 50 years, sedimentation likely will affect flood control capability as storage is further reduced in some reservoirs.

b. Study Objectives

Future study objectives could include the following:

- Remediate the major structural problems at Muskingum projects, such as the foundation problem at Dover Dam and eliminate embankment seepage at Bolivar, Beach City, and Mohawk Dam under the Dam Safety Assurance and Major Rehab programs;

- Complete remediation of hydraulic deficiencies at Atwood, Clendening, Dillon, Dover, Piedmont and Pleasant Hill under the Dam Safety Assurance program;

- Determine if providing gated outlets at Bolivar, Dover, Mohawk, and Mohicanville which were projects constructed as dry dams is economically feasible and would improve efficiency of the overall system;

- Minimize the impacts of sedimentation at the lakes either by controlling the deposition location or by removing sediment from the pools;

- Minimize further deterioration of concrete linings in outlet tunnels at five projects (Atwood, Clendening, Leesville, Piedmont, and Tappan) by construction of multi-level intakes to reduce acidity in the water released from the lakes;

- Improve stream channels in the Muskingum Basin with extensive erosion problems through a comprehensive program of bank stabilization and environmental restoration;

- Reduce flood damages at several identified locations in the Muskingum Basin by the implementation of feasible structural or non-structural measures;

- Renovate water and sewage treatment plants where infrastructure problems exist or facilities are inadequate;

- Determine the impacts of reductions in the original channel outflow capacity below various reservoirs because of floodway encroachment, and evaluate potential changes to improve outflow capacity based on current conditions;

- Review accuracy of 10 river gages downstream of the Muskingum reservoirs and determine if floods have higher stages now than originally established because of changes in channel capacity;

- Determine the need for modification or relocation of inaccurate outflow gages so that maximum discharges can be efficiently maintained;

- Determine the need for and the economic feasibility of installing a flood warning system in the Muskingum Basin in cooperation with State and Local officials;

- Evaluate winter drawdown at the Muskingum reservoirs and determine the impacts of changes on shoreline erosion and flood control storage;

- Evaluate shallow water problems at some lakes and the impacts on recreational use, and determine if options such as removal of sediment, raising pool elevations or a combination of these alternatives is practical and economically feasible;

- Determine if the projects that can only release water from the bottom of the lake should be modified to provide multi-level withdrawal capabilities thereby improving water quality downstream and reducing erosion of the outlet tunnels;

- Conduct surveys of the Muskingum Basin to determine environmental problems or needs that can be addressed as part of a comprehensive environmental restoration program, particularly streams with acid mine drainage or extensive bank erosion; and

- Conduct detailed analysis to determine if there are economically feasible measures which can effectively reduce flood damages at identified locations throughout the Muskingum Basin.

c. Study Constraints

Constraints on any future studies are as follows:

- Project infrastructure improvements must be technologically feasible and cost effective;
- Improvements for flood damage prevention and recreation shall have benefits in excess of cost;
- Ecosystem restoration projects must contribute significantly to the basin ecosystem and the nation;
- Ecosystem Restoration plans and benefits must be reasonable when compared to project cost;
- Improvement plans must be within the authority of the Corps of Engineers and the non-federal sponsor to implement; and
- There must be reasonable assurances that a State or local unit of government is capable and willing to participate as a non-Federal sponsor in a cost shared feasibility study as well as the implementation of improvements at MWCD projects.

d. Alternatives Considered

This section discusses alternative measures that have been given consideration in solving the water resource problems or meeting needs discussed in Chapter 3. Any costs or impacts utilized for this initial screening of alternatives have been developed without the benefit of detailed engineering or environmental studies such as geotechnical, hydrologic investigations or ecological field studies. Alternatives that appear to effectively address identified problems and exhibit the potential for economic feasibility will be retained for further evaluation, while some measures may be dropped from further consideration.

(1) Hydraulic Deficiency

Hydraulic deficiencies have been corrected at eight projects – either by raising the dam, widening the spillway or both. Similar measures are anticipated at six other reservoirs that have been classified under the DSA program as having hydraulic deficiencies. Piedmont has been investigated and the remedial measures recommended include raising the dam embankment with a parapet wall and constructing a concrete cutoff wall to prevent erosion of the unpaved portion of the spillway. When a PCA is finalized the recommended improvements will be completed and become part of the baseline condition. Investigations under the DSA program are scheduled for Clendening, Atwood, Pleasant Hill, and Dillon, to determine the extent of the hydraulic deficiencies at these projects. It is anticipated that alternatives similar to those undertaken at Piedmont will be recommended for these projects and the remedial measures will be completed prior to 2010.

Dover Dam, the remaining project with hydraulic deficiencies, is a concrete gravity dam and the structural problems are different from the other projects. The dam does not meet current design criteria, and the PMF would overtop the dam by nearly 6 feet. The dam height may need to be raised, and the spillway capacity increased, which could require adding an auxiliary spillway at the abutment. According to earlier investigations, Dover Dam also is an unstable gravity structure. At a very high pool, the dam could fail by sliding, resulting in the formation of a shear plane through several of the spillway monoliths which are founded on a silty-shale. Stabilizing the dam could require anchoring the structure to the sound limestone foundation located below the weak shale layer. Further geotechnical and structural studies including foundation exploration are necessary before satisfactory remedial measures can be completed at Dover.

Three projects have major seepage problems through the dam embankment. Bolivar is the most critical of the projects, but Mohawk and Beach City also are of concern. Investigations have indicated that several areas of the dam embankment or the foundation at these projects would become unstable due to piping at a pool less than spillway crest level. Additional geotechnical studies are necessary to determine the full extent of the seepage problems. However, based on similar conditions at other Corps projects, a concrete cut-off wall would be a likely measure to be considered. A cut-off wall could be extended through the dam embankment to bedrock, providing an effective barrier through the embankment to full foundation depth. Indications are that remedial measures will be completed for Bolivar prior to 2010, but corrective measure for Mohawk and Beach City may be designed, but construction will not have been completed by 2010.

(2) Reservoir Operations

The operation of the Muskingum Reservoir system is complex and requires significant flexibility to meet the needs of communities in the basin. Over the past 70 years operations have been modified to accommodate local communities because of problems that have arisen due to economic development and changing land uses. These changes have somewhat reduced the effectiveness of the Muskingum projects to meet the authorized purposes of flood control and recreation.

A comprehensive review of operation of the Muskingum projects is necessary. This evaluation would require utilizing existing models, such as the Systems Thinking in an Experimental Learning Lab with Animation (STELLA) Model, to determine scenarios to optimize operation of the system. The STELLA Model was developed as part of the early planning process of the Muskingum study.

As part of this study, the USACE conducted an optimization study using the STELLA Model to evaluate alternatives that include the consideration of reservoir flood control elevations during both winter and summer, flood damage assessment for river flows, loss of flood storage due to sedimentation, water supply availability, recreational impacts of winter pool drawdown and filling times, water quality outflow minimums, dry/wet project operation for storage balancing, and other potential uses. The Muskingum Reservoir System Optimization Study Report is at Appendix D.

The main considerations in evaluating the alternatives in the Optimization Study included economic impacts, water control impacts and water supply allocations. The primary tool used to evaluate the study alternatives is a revised version of the Muskingum River Basin Model, which runs on the STELLA Model High Performance Systems, Incorporated software. The model includes 16 lakes and 13 downstream controls. It simulates lake releases in response to seasonally based operational controls and historical inflow data. Additional models may be utilized which will allow for evaluation of recreation and environmental alternatives.

To facilitate the analysis revisions were necessary to make the model work effectively. These revisions involved updating the period of record, adding control stage damage cost relationships, project geometry updates and a significant amount of model logic code revision. All of these changes were verified for accuracy so that they closely matched existing operations for the Muskingum Basin. These changes were included in the base-case model, before adding new logic to evaluate the efficiency of subsequent model operation alternatives.

Twelve optimization alternatives were evaluated and provide important information regarding potential changes in lake operation rules. The most beneficial change that could be made is to repair the structural deficiencies at Bolivar Dam and Dover Dam, which would significantly reduce downstream flood damages. The next most beneficial change would be to make control modifications on the siphons at Tappan, Clendening and Piedmont, which are causing releases from those projects to frequently exceed flood stages at the communities of Tippecanoe and Uhrichsville. It should be noted, all of these potential modifications from the alternative studied would require further study with careful considered before being adopted into the water control plan.
It is clear from stakeholder input that there is significant interest in basin-wide ecology and in operational alternatives to address these concerns. Significant data and analysis is required before such alternatives can be formulated and evaluated.

Environmental models may be developed which will consider operational changes that benefit the downstream water quality of projects. Recent studies in other Corps

Districts have found that slight changes in the operating parameters greatly influences fish spawning and greater productivity for other riverine species. For example, the Louisville District partnered with The Nature Conservancy in evaluating changes to operating parameters at the Green River Reservoir in Kentucky and this procedure is considered appropriate for a majority of the Muskingum Reservoirs. Additionally, alternatives need to be evaluated for balancing recreation resources throughout the basin and would include evaluating water releases to benefit canoe liveries. Other alternatives that will be considered include operational changes that could normalize water temperature in the tail waters and cause fluctuations in the seasonal pool to promote vegetation of sandbars and mudflats.

(3) Sedimentation in Lakes

Sedimentation has adversely affected MWCD reservoirs in several ways – diminished lake area for boating, siltation of facilities such as beaches and boat ramps, reduction of storage for downstream flow releases or water supply withdrawals, and degradation of the quality of water in the lakes. The problems are most significant at Beach City and Wills Creek, which have lost nearly their entire conservation pool, but also at Dillon and Charles Mill lakes. Projections for the next 50 years indicate that sedimentation may significantly impact several more of the Muskingum lakes. Summaries for sedimentation at the Muskingum lakes are given in Table 3.

There are a number of alternatives available to deal with the lake sedimentation. The "no action" alternative would let the influx of sedimentation continue unabated and adjust the use and purposes of the lakes accordingly. Lake recreation at projects such as Beach City and Wills Creek would be almost totally lost, and recreation at Dillon and Charles Mill would be significantly reduced because the available lake areas for boating and fishing would be greatly diminished. Even if sediment influx remains uncontrolled, there are opportunities for managing the sediment deposition in the lakes. Training devices such as geotubes can help trap and divert sediment entering the lake and control somewhat the location of deposition. The areas of controlled sediment could then be developed for beneficial use such as wetlands, which is one of the alternatives now being considered at Dillon Lake.

Another alternative is to reduce sediment at its source. Sediment originating from bank erosion on rivers and streams in the watersheds above the reservoirs may be reduced with streambank stabilization techniques, which in turn would reduce the sediment load reaching the lakes. If sediment entering the lakes is reduced, then measures to trap or redirect sediment in the lakes have a greater likelihood of success. Some techniques to reduce bank erosion and the sediment entering lakes are currently being investigated for the Licking River Watershed. These measures are described in Section 4.E.(1), "Managing Lake Sediment".

Raising reservoir pool levels to increase the sediment storage have been considered as a means of postponing the sediment problem until removal options can be accomplished. However, the consequences of raising the pools are significant. If the summer pool is raised to provide adequate depths for boating and fishing, the total flood control storage is then reduced. Maintaining the flood control storage could mean raising the dam along with addressing flowage easement problems associated with a higher flood control pool.

Another alternative is to remove sediment from the lakes by dredging. In an effort to return lakes to their original depths, sediment could be removed by hydraulic dredging and the slurry material pumped to deeper parts of the lake or to an upland disposal site. Dredging has been accomplished at Dillon Lake in the vicinity of the swimming beach. This was a small-scale operation and the dredged material was disposed of nearby in a deeper area of the lake. Dredging at Dillon on a large scale in an attempt to return the lake to its original depths has been determined to be economically and environmentally infeasible, because of excessively high cost and lack of acceptable disposal sites. There may be some Muskingum Lakes where dredging on a small scale can eliminate some sedimentation problems, and help maintain some facilities such as beaches and boat launching ramps available for public use. However, unless the conditions that are causing the sediments to enter the stream channel are addressed, this will be a short-term remedy and may not be the most efficient use of funds.

(4) Lake Quality and Pollution

The water quality of the Muskingum Lakes have been monitored since the 1970's to determine trends over a temporal period, and to address existing and potential water quality problems. Operational challenges, changing land use, and impacts of growth are all affecting the water quality of the reservoirs.

Two of the most significant water quality problems at the Muskingum projects are chemicals entering the lakes and the inability to release water from various water depths of the lakes. Water quality of the lake bottom is degraded due to pollutants entering the stream from past mining operations and various other point and non-point sources. The addition of a selective withdrawal structure would allow for mixing the water from various levels of the lake. This would improve water quality downstream by increasing dissolved oxygen. Temperature could also be improved in the tailwater area of the lakes by installing a selective withdrawal feature.

(5) Watershed Planning and Restoration

Four specific watershed problems that will be investigated by the Corps of Engineers, MWCD and various other organizations under this initiative are stream and riparian restoration, acid mine drainage remediation, and water and sewer infrastructure improvement projects. Addressing these types of problems is within existing Corps' authorities and also within the general planning expertise of the Corps. Some examples include the Monday Creek Ecosystem Restoration project, which looked at problems associated with AMD, and the Dillon Lake and Licking River Watershed Feasibility Study which investigated measures to reduce sedimentation through stream and riparian restoration. There are also several environmental infrastructure projects which are designed to improve water and sewer facilities in local communities under the Section 594 Program.

Over 185 localized AMD sites within the Muskingum Basin have already been identified by the Ohio Department of Natural Resources. A comprehensive detailed evaluation will be necessary to determine the magnitude of the problem and the feasibility of patented alternative solutions. A comprehensive approach could include several of the measures previously discussed or a combination of alternatives may prove the most successful for remediation within the Muskingum Basin. See Table 4 for a county-by-county listing of surface and underground abandoned mined land sites in the Muskingum Basin.

A comprehensive ecosystem restoration plan is also needed to address the various stream and riparian restoration challenges in the basin. Stream and riparian areas in the Muskingum Basin provide important habitat to many species. Changes to the composition and function of these areas are resulting in elevated sedimentation levels in the rivers and reservoirs throughout the Muskingum Basin.

Possible measures for restoring streams and riparian zones in the Muskingum Basin may evolve from alternatives being developed as part of the Licking River Watershed Feasibility Study. In the Licking River Watershed study the alternatives focused on alleviating excessive sedimentation entering Dillon Lake and included an evaluation of measures for restoration of the stream and riparian system. The study identified denuded riparian areas, where development has infringed upon the riparian corridor. The riparian area could be improved through better management practices and modifications to streams such as minor regrading and hydrologic connections to the river, and stabilization of stream banks and channels.

Alternatives could include the establishment of riparian corridors using criteria that prescribes a minimum required buffer based on the size of the upstream watershed. For instance, a minimum 75 feet of riparian buffer would be established on either side of a stream with a contributing upper watershed of 20 square miles. For watersheds greater than 300 square miles, a minimum of 200 feet would be established on either side of the stream.

A slightly different stream stabilization design would be utilized in areas where the stream channel is entrenched. Unstable streams usually erode through either lateral migration or downward erosion. Downward or entrenched channels require more detailed field data and the actual design may be more complex than for unstable banks alone.

Another alternative would involve improving the riparian corridor and the stream by adding sinuosity to a stream by developing bends or oxbows in a particular section of the channel. Some problem areas might warrant a combination of some or all of the above-mentioned stream and riparian restoration technique.

These problem areas can only be identified after a detailed reconnaissance of the major sub-watersheds and other streams in the Muskingum Basin. Geographic Information Systems (GIS), remote sensing and field reconnaissance all would be utilized to identify the locations where unstable banks and stream channels are a major problem.

Several hundred locations within the Muskingum Basin have been identified by the Ohio Environmental Protection Agency and other agencies that have a need for modernization of basic water and sewer services. The problems and needs range from renovation of water and sewage treatment plants to the installation of water and sewer lines. The Corps currently has a program to address water and sewer line infrastructure problems within the State of Ohio under authority of Section 594 of the 1999 Water Resources Development Act (PL 106-53). This program has already proved successful at several locations in the state and a similar program could be developed solely for the Muskingum Basin. See Figure 6 for the location of Section 594 projects within the Muskingum Basin.

(6) Flood Damage Reduction

There are a number of locations throughout the Muskingum Basin where flooding is a serious problem, mostly in areas not protected by the reservoirs. Over the past 25 years, several of the damage centers have been investigated by the Corps. Projects have not been constructed at these locations for various reasons; some are not economically feasible, some are lacking local support, and some because of significant environmental problems. However, it is anticipated that several of these locations, plus others such as Zimber Ditch and Nimishillen in Stark County, will be investigated in light of increased development in these areas and the Corps' current emphasis on non-structural approaches to flood damage reduction. Improvements such as retarding dams and large multi-purpose reservoirs could be investigated, but there is extensive reservoir control in the basin and the cost of such major development is very high and the impacts of construction are significant.

A plan for a flood warning system has been developed and is at Appendix E. A flood warning system would give the National Weather Service (NWS) and emergency management agencies the capability for providing basin-wide emergency storm and flood warnings. A computerized network would tie together automated rain and stream gages and provide current gage readings to the State Emergency Operation Center, the Ohio DNR, the NWS, and county emergency management officials. The automated data system would alert the agencies to potential flooding situations in the Muskingum Basin.

e. Alternatives to be Investigated

Alternatives that present the most potential for meeting needs and solving identified water resource problems are discussed in this section. These alternatives will be investigated further, while some alternatives previously described, but don't appear to be feasible or effective, have been eliminated from further consideration. Formulation of final alternatives requires additional technical data such as design and cost estimates, economic analysis and assessment of project impacts. That data, however, is not available at this stage of investigations; therefore, the discussion and evaluation of alternatives are based largely on prior experience and professional judgment of the project delivery team. A summary of alternatives to be considered is provided in Table 6.

Hydraulic and structural deficiencies have already or are scheduled to be corrected if funding is available at thirteen MWCD projects by 2010, and therefore are part of the designated baseline condition. One of the projects which has serious deficiencies and will not be corrected by 2010 is Dover Dam. It does not meet current design criteria and is an unstable concrete gravity structure. Raising the dam elevation and adding spillway capacity will be investigated as alternatives to correct the hydraulic deficiencies. Anchoring the dam foundation could be a means of stabilizing the dam structure against sliding failure. Under the Corps' national Screening Portfolio Risk Analysis (SPRA) that evaluated 60 of the Corps' riskiest dams in 2005, Dover Dam was ranked number 9. (See Table 7.)

Three of the Muskingum dams have significant seepage problems, where at high pool levels the embankment can become unstable due to piping. Based on similar conditions at other Corps projects, it is anticipated that concrete cutoff walls will be investigated as a means of providing an effective barrier through the dam embankment to bedrock. Under the SPRA, Mohawk was ranked number 7, Bolivar number 11, and Beach City number 18 as the Corps' riskiest dams in need of attention. A similar approach to the cutoff concrete wall will also be investigated at Zoar Levee in the Dover pool which also has seepage problems. Table 7 lists the Corps' top 20 riskiest dams.

Table 6. Alternatives to be investigated for solving water resource problems in the Muskingum Basin.

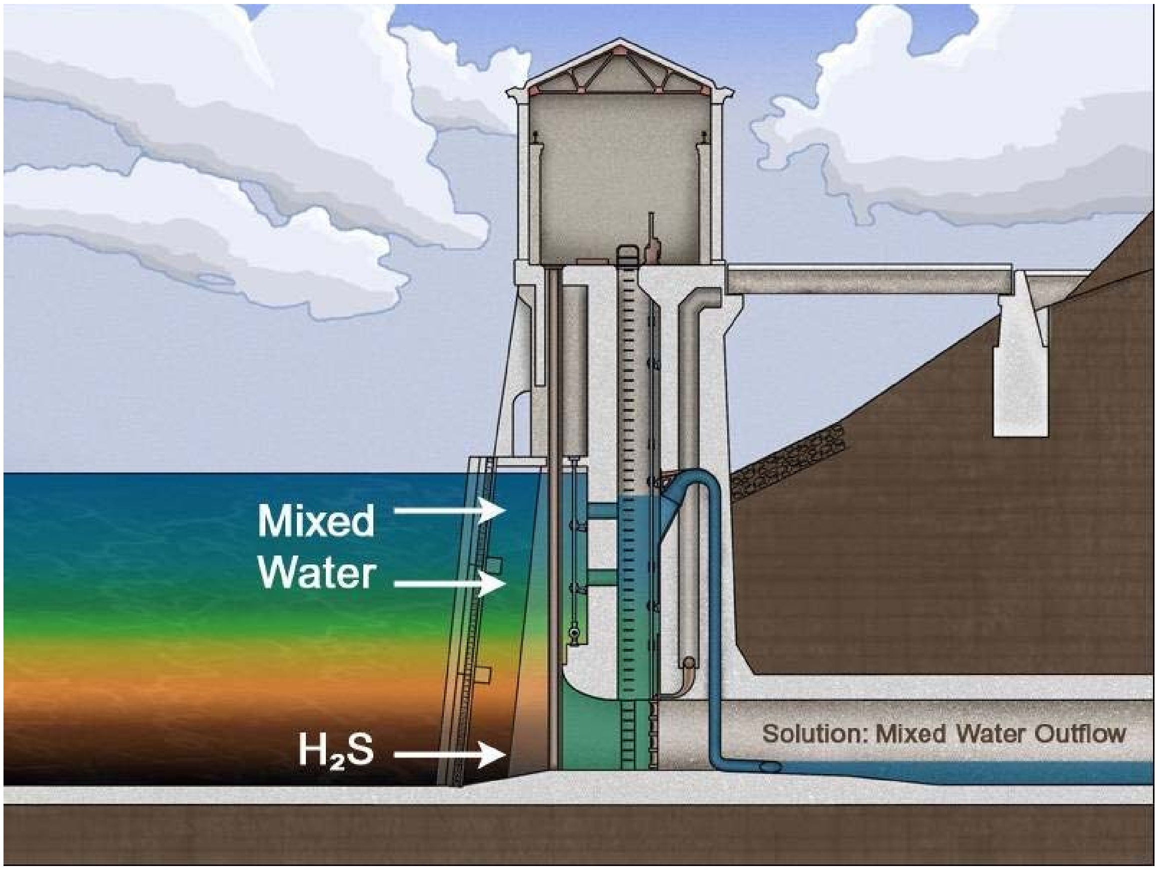
Alternatives	Corps Authority	Effectiveness	Relative Cost	Environmental Impacts	Local Support	Agency Cooperation
Hydraulic & Structural Deficiencies						
• Raise Dam Embankment	DSA	High	High	Minor	Yes	Yes
• Widen Spillways	DSA	High	High	Moderate	Yes	Yes
• Dam Cutoff Walls	O&M	High	High	Minor	Yes	Yes
• Multi-Level Intakes(Tunnel Erosion)	O&M	Moderate	Medium	Minor	Yes	Yes
Managing Lake Sediment						
• Geotubes	CG	Moderate	Medium	Minor	Yes	Yes
• Dredging	O&M	High	Very High	Major	Yes	Mixed
• Raising Pool Levels	O&M	Moderate	Medium	Moderate	Mixed	Mixed
Flood Damage Reduction						
• System Optimization	O&M	High	Low	Minor	Yes	Yes
• Modifying Dry Dams	O&M	Low	Medium	Major	Mixed	Mixed
• Flood Protection Projects	CAP	High	Moderate	Moderate	Yes	Yes
Environmental Restoration						
• AMD Restoration	CAP	High	Moderate	Minor	Yes	Yes
• Stream Restoration	CAP	High	Low	Minor	Yes	Yes
• Riparian Restoration	CAP	High	Low	Minor	Mixed	Yes
• Water & Sewer Projects	Section 594	High	Moderate	Minor	Yes	Yes

Table 7. The Corps' Riskiest Dams from the Screening Portfolio Risk Analysis.

Ranking	Project
1	Isabella
2	Center Hill
3	Martis Creek
4	Success
5	Wolf Creek
6	Salamonie
7	**Mohawk**
8	J.E. Roush
9	**Dover**
10	Hop Brooke
11	**Bolivar**
12	Canton
13	Clearwater
14	Bluestone
15	Rough River
16	Ball Mountain
17	J. Redmond
18	**Beach City**
19	Lookout Point
20	H. Hoover 1-3

Outlet tunnels at five of the Muskingum reservoirs have deteriorated concrete linings, which has been attributed to the acidic effect of hydrogen sulfide which forms near the lake bottom. A multi-level intake which allows water to be discharged from various levels in the lake is now being investigated at Tappan Lake. These intakes allow higher quality water to be discharged downstream and this should reduce or eliminate the deterioration of the tunnel lining. If successful at Tappan, similar intake designs will be investigated at Atwood, Clendening, Leesville, and Piedmont Lakes. Figure 7 is an illustration of the proposed modification to the intake structure at Tappan Lake.

Figure 7. Proposed Modification of Intake Structure to Minimize Effect of Hydrogen Sulfide.



(1) Managing Lake Sediment

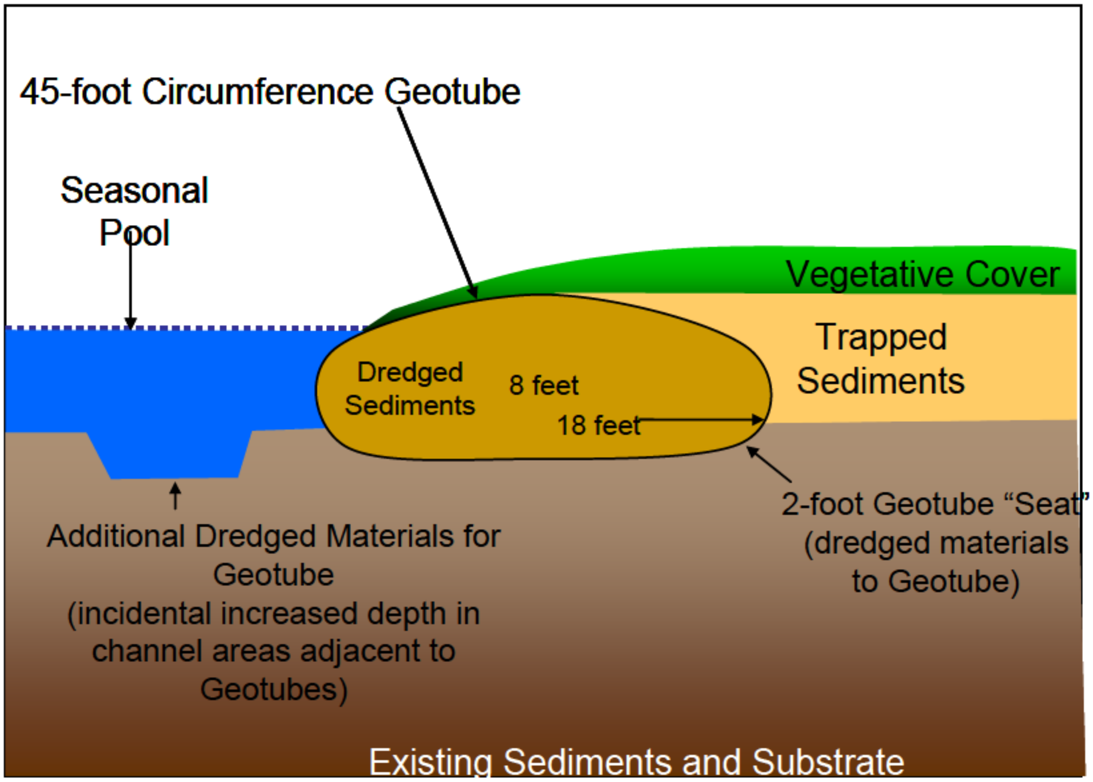
One of the big challenges of ecosystem restoration in the Muskingum Basin is controlling sedimentation in the rivers and lakes. Sedimentation has adversely affected several of the Muskingum lakes, with the most serious problems occurring at Beach City, Wills Creek, and Dillon Lakes. For example, sediments have closed two boat launching ramps and a popular swimming area in Dillon Lake. (See Photo 7.) Doing nothing about the widespread problems is not an acceptable option, since remedial measures undoubtedly will be necessary over the next 50 years at some projects. Locating and addressing the sources of deposition in the streams above the lakes may provide the most beneficial long-term solution. However, the approach may be cost prohibitive.

Photo 7. Dillon Lake Boat Launching Ramp Closed due to Sedimentation.

The potential for bank erosion could be reduced by implementation of stream channel setbacks and restoration of the riparian zone. Riparian corridors could be established by acquiring easements along both sides of the streams, where the riparian buffer would vary in width depending on the size of the upstream watersheds, from a minimum of 50 feet up to 200 feet. Many of these channel stabilization techniques are currently being investigated as part of the Licking River Watershed Ecosystem Restoration Study and could have applicability to other watersheds throughout the Muskingum Basin. The source of much of the sedimentation is bank and channel erosion in the watersheds above the lakes. In order to help reduce erosion, several bank stabilization measures will be evaluated in future studies. These measures could involve a bioengineering application, using materials such as coil fabric revetment, live willow stakes and other bank plantings. Live crib walls of stacked timbers, filled with earth and stone materials, and planted with regional vegetation, may have application for some situations. More traditional stream bank revetment using gabions or rip-rap may be the most effective technique in reaches around public infrastructure and other facilities. If there is an entrenched channel with erosion in the stream bottom, restoration may require excavation and regrading of bank material to create more stable channel slopes and provide additional flood carrying capacity beyond the limits of the existing channel. Also, incorporating natural channel design features such as increasing sinuosity by adding meanders and oxbows, or by introduction of pools and riffles in a stream, could reduce the stress on the banks and diminish bank erosion.

Another alternative that could help manage the deposition of sediment in the lakes involves the installation of sediment training devices such as geotubes. (See the illustration at Figure 8.)

Figure 8. Cross-sectional View of a Geotube. Such devices, while not reducing sediment inflow, can help trap and direct the sediment to the most desirable locations.



The use of geotubes currently is being investigated at Dillon Lake and if determined to be feasible they can be applied at other lakes with sedimentation problems. Photos 8 and 9 show a geotube installed at Drakes Creek in the Nashville District immediately following installation, and sometime after vegetation had naturally established.

Photo 8. Geotube immediately following placement.

Photo 9. Geotube with established vegetation sometime after placement.

Another option for sediment management is to actually remove material from the lakes by dredging. Sediment removal in large quantities necessary to return lakes to their original depths is probably not feasible as investigations have indicated at Dillon. However, it is anticipated that dredging on a more limited scale will be investigated at several Muskingum reservoirs. The following is a summary of sedimentation data at each of the lakes.

- Atwood – The latest sediment survey for Atwood Lake was in 1999 and the report was published in 2002. At the time of the 1999 survey, the estimated sediment volume below seasonal pool (elevation 928 feet) was 3,230 acre-feet as compared to an original seasonal pool volume of 24,250 acre-feet. The sediment volume is equivalent to a 13 percent loss in lake storage capacity between April 1940 and May 1999. The rate of sedimentation was computed to be 54.6 acre-feet per year or 0.81 acre-feet per year per square mile of contributing drainage area. At that current sedimentation rate, it would take approximately 385 years to deplete the remaining seasonal pool capacity.

- Beach City – The latest sediment survey for Beach City Lake was in 1993 and the report was published in 1995. At the time of the 1993, survey the estimated volume below the flood control pool (elevation 976.50 feet) was 5,911 acre-feet as compared to an original flood pool volume of 71,700 acre-feet. The rate of sedimentation at flood control pool was computed to be 104 acre-feet per year or 0.36 acre-feet per year per square mile of contributing drainage area. For all practical purposed, the minimum pool capacity (below elevation 948 feet) has been completely depleted from its original capacity.

- Bolivar – There is no data available.

- Charles Mill – The latest sediment survey for Charles Mill Lake was in 1998 and the report was published in 2002. At the time of the 1998 survey, the estimated sediment volume below the minimum pool (elevation 997 feet) was 1,870 acre-feet as compared to an original minimum pool volume of 7,330 acre-feet. The rate of sedimentation was computed to be 31 acre-feet per year or acre-feet per year per square mile of contributing drainage area. At the time of the 1998 survey, approximately 25 percent of the minimum pool capacity has been depleted.

- Clendening – There have been no sediment surveys conducted at Clendening Lake until 2004. The analysis is not complete, and the 2004 survey report has not been published due to Operations and Maintenance (O&M) funding restrictions.

- Dillon – The latest sediment survey for Dillon Lake was in 1998 and the report was published in 2002. At the time of the 1998, survey the estimated sediment volume below the seasonal pool (elevation 737 feet) was 6,400 acre-feet as compared to an original seasonal pool volume of 17,000 acre-feet. The rate of sedimentation at seasonal pool was computed to be 170 acre-feet per year or 0.25 acre-feet per year per square mile of contributing drainage area. At that current sedimentation rate, it would take approximately 60 years to deplete the remaining seasonal pool capacity.

- Dover – There is no data available.

- Leesville - The latest sediment survey for Leesville Lake was in 2001 and the report was published in 2001. At the time of the 2001 survey, the estimated sediment volume below the seasonal pool (elevation 963 feet) was 2,542 acre-feet as compared to an original seasonal pool volume of 19,999 acre-feet. The rate of sedimentation at seasonal pool was computed to be 39.2 acre-feet per year or 0.84 acre-feet per year per square mile of contributing drainage area. At that current sedimentation rate, it would take approximately 445 years to deplete the remaining seasonal pool capacity.

- Mohawk – There is no data available.

- Mohicanville – There is no data available.

- North Branch Kokosing River - The latest sediment survey for North Branch Kokosing River was in 1993 and the report was published in 2004. At the time of the 2003 survey, the estimated sediment volume below the seasonal pool (elevation 1,121 feet) was below 220.82 and 221.93 acre-feet as compared to an original seasonal pool volume of 930.80 acre-feet. The rate of sedimentation at seasonal pool was computed to be 7.2 acre-feet per year or 0.16 acre-feet per year per square mile of contributing drainage area. Approximately, 24 percent of the seasonal pool capacity has been depleted.

- Piedmont – The latest sediment survey for Piedmont Lake was in 1998 and the report was published in 2001. At the time of the 1998 survey the estimated sediment volume below the seasonal pool (elevation 913 feet) was 7,540 acre-feet as compared to an original seasonal pool volume of 36,922 acre-feet. The rate of sedimentation at seasonal pool was computed to be 125 acre-feet per year or 1.52 acre-feet per year per square mile of contributing drainage area. At that current sedimentation rate, it would take approximately 275 years to deplete the remaining seasonal pool capacity.

- Pleasant Hill – The latest sediment survey for Pleasant Hill Lake was in 1998 and the report was published in 2001. At the time of the 1998 survey, the estimated sediment volume below the seasonal pool (elevation 1,020 feet) was 3,570 acre-feet as compared to an original seasonal pool volume of 14,400 acre-feet. The rate of sedimentation at seasonal pool was computed to be 56.9 acre-feet per year or 0.35 acre-feet per year per square mile of contributing drainage area.

- Senecaville – The latest sediment survey for Senecaville Lake was in 1998 and the report was published in 2002. At the time of the 1998 survey, the estimated sediment volume below the seasonal pool (elevation 832.2 feet) was 10,100 acre-feet as compared to an original seasonal pool volume of 44,500 acre-feet. The rate of sedimentation at seasonal pool was computed to be 162.9 acre-feet per year or 1.45 acre-feet per year per square mile of contributing drainage area. At that current sedimentation rate, it would take approximately 200 years to deplete the remaining seasonal pool capacity.

- Tappan – The latest sediment survey for Tappan Lake was in 1998 and the report was published in 2002. At the time of the 1998 survey, the estimated sediment volume below the seasonal pool (elevation 899.3 feet) was 6,900 acre-feet as compared to an original seasonal pool volume of 35,840 acre-feet. The rate of sedimentation at seasonal pool was computed to be 109.8 acre-feet per year or 1.64 acre-feet per year per square mile of contributing drainage area. At that current sedimentation rate, it would take approximately 260 years to deplete the remaining seasonal pool capacity.

- Wills Creek - The latest sediment survey for Wills Creek Lake was in 2002 and the report was published in 2003. At the time of the 2002 survey, the estimated sediment volume below the seasonal pool (elevation 742 feet) was 4,580 acre-feet as compared to an original seasonal pool volume of 5,700 acre-feet. The rate of sedimentation at seasonal pool was computed to be 69.2 acre-feet per year or 0.123 acre-feet per year per square mile of contributing drainage area. At that current sedimentation rate, it would take approximately 16 years to deplete the remaining minimum pool capacity. Refer to Table 3 to see the changes in conservation storage due to sedimentation.

(2) Watershed Ecosystem Restoration

The Muskingum Basin is a large basin and it has many environmental problems and needs. To facilitate formulation of alternatives for such a matrix of problems, analysis has been focused on four general categories of problems and needs: Acid Mine Drainage (AMD), stream erosion, riparian degradation, and water and sewer deficiencies. The following paragraphs discuss alternatives that are likely to be investigated because they have the greatest potential for solving the major environmental problems and restoring the ecosystem.

AMD is prevalent throughout the Muskingum Basin, as several hundred sites have already been identified. (See Photo 10.) The Corps recently has completed and ecosystem restoration study on Monday Creek in the adjacent Hocking River Basin which evaluated a number of potential measures for reducing and controlling AMD. Several of these measures appear to have application in the Muskingum Basin, particularly on a stream with major AMD problems such as Moxahala Creek. The general approach for AMD remediation is to use alkaline materials to neutralize the acidic content of rivers and streams. This can be accomplished by using either active measures, which require continual maintenance, or passive measures which generally are self sufficient and have a much longer design life. Active measures include dumping limestone in streams by the truckload and adding additional limestone as the fines dissolve, or constructing a more permanent facility which provides alkaline materials to a stream on a regular basis by limestone dosing. Passive measures include construction of buried limestone drains designed to limit oxygen contact with acid mine drainage (anoxic) or open limestone drains or channels on steep slopes that will precipitate metals from the acid water. Wetlands can be developed which would help neutralize AMD. These wetlands would use vegetation planted in shallow, impermeable sediments of clay or mine spoil, in conjunction with permeable organic mixtures underlain with limestone. Restoration projects involving use of wetlands to reduce AMD have been completed by the Corps on Wills Creek upstream of the reservoir and by the Ohio DNR on Huff Run.

Photo 10. Acid Mine Drainage Site Located within the Muskingum Basin.

Inadequate water and sewer systems are another major problem in the Muskingum Basin that could be addressed in a basin wide comprehensive program. Several hundred sites have been identified by the Ohio EPA that has a need for upgrading or total replacement of existing water and sewer systems. Under the Corps' Environmental Infrastructure Program, Section 594, several projects are underway in the Muskingum Basin, such as a major wastewater treatment plant at Zanesville and storm water facilities at McConnelsville. (See Figure 6 for the locations of active Section 594 Projects in the Muskingum Basin.) The most effective means of addressing the hundreds of problem areas is to assess the facility needs using a basin-wide or sub-basin comprehensive approach, particularly in the watersheds upstream of the Muskingum reservoirs. Once the major problems have been assessed, the needs can be prioritized and improvements undertaken using the existing Section 594 authority as applicable, or by securing special basin-wide authority for environmental infrastructure improvements in the Muskingum Basin.

(3) Flood Damage Reductions

The Muskingum reservoirs are operated during flood conditions much the same way as when the system was originally completed in the 1930's. Structural deficiencies have reduced the effectiveness of a few projects, but modernization should again restore the full flood reduction capability of these projects. A system optimization study was completed (see Appendix D) and some management measures being considered could actually increase the overall effectiveness of the reservoir system. Four of the MWCD projects are dry dams, with limited controls for storing and releasing floodwaters. Investigations will determine whether providing additional controls at these "dry dams" could increase the flood damage reduction capability of the overall Muskingum System.

A number of flood damage centers in the Muskingum Basin which are not protected by the reservoir have previously been investigated by the Corps. It is anticipated that several communities, in particular Canton, Mansfield, Cambridge, Crooksville, Killbuck, Millersburg, and Uhrichsville, will be included in future flood damage investigations. Some of the locations already have preliminary designs for flood protection projects, and others have recently indicated a need for flood protection. Both structural and non-structural approaches for flood damage reduction will be included in the future investigations.

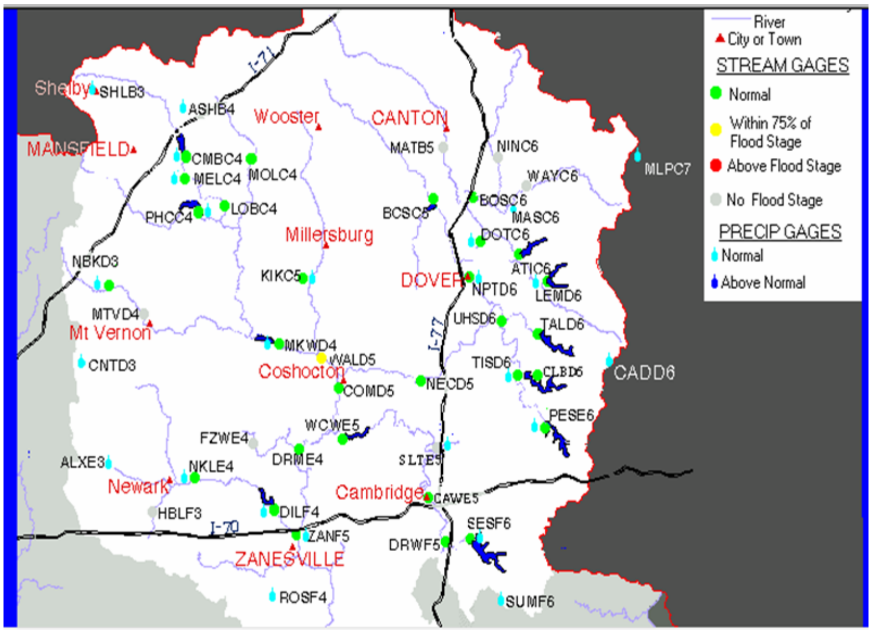
A flood warning system can be an affective program to complement structural flood damage reduction measures traditionally developed by the Corps. The plan was completed by the Corps in 2004 for a flood warning system in the Muskingum River Basin. A copy of the plan is at Appendix E. This warning system would be a coordinated effort between the Corps, the National Weather Service (NWS), the Ohio

Emergency Management Agency (OEMA), and the US Geological Survey (USGS). The primary components or measures necessary to implement the flood warning system are:

- Upgrading existing USGS and Corps recording gages (see Figure 9) to transmit GOES data every hour with high data rate transmitters and develop capability to use ALERT protocol,
- Install additional rain gages as part of STORMS automated system,
- Install new USGS stream gages,
- Develop automated data exchange mechanism of the ODOT to transmit data to the OEMA STORMS systems,
- Create web-based data dissemination system for the STORMS program,
- Establish data sharing protocols between state and federal agencies,
- Provide real-time alerts to emergency managers regarding stream stages,
- Upgrade available Geographic Information System (GIS) coverage and support technology,
- Support completion of NOAA Weather Radio coverage of Ohio,
- Enhance public awareness of flood threats and notification technology,
- Update flood response plans.

The planning and design of the flood warning system requires further refinement, but if cost sharing partners are secured, the system could be implemented in a few years.

Figure 9. Muskingum Stream and Precipitation Gages



5. Preliminary Cost Estimate

The Muskingum reservoirs have been operated much the same since their construction in the 1930s. Demand on these projects has increased and has compounded with age, while operation and maintenance funding has remained relatively the same. Short-term fixes, funded from limited revenue sources, have managed to keep the system functional. But some features no longer provide for public safety as originally authorized so now revitalization – not simply maintenance – is required. The Corps has identified hundreds of projects, large and small, many of which are critical to public and environmental safety. A comprehensive infrastructure report (Appendix A) has been prepared listing structural deficiencies of each of the 16 flood control projects. The preliminary cost estimate for correcting these structural deficiencies is $553 million and a summary breakdown of this figure, by problem area, is given in Table 8 under the heading “infrastructure”.

As a first step in correcting many of the basin’s structural deficiencies, detailed mapping will need to be developed. Therefore, a GIS, Mapping and Surveying Plan were developed as part of this study. The plan identifies the stream reaches to be mapped, the priority of the reaches, and the level of detail required. The estimated cost for surveying and mapping limited study areas within the Basin is $18 million and this does not include LIDAR. This cost is part of the $553 million identified under the infrastructure heading below and the GIS, Mapping and Surveying Plan can be found at Appendix F.

Table 8. Preliminary Total Project Cost Estimate.

Water Resource Problems	Estimate	Contingency	Preliminary Cost
Infrastructure	**$443,000,000**	**$110,000,000**	**$553,000,000**
Hydrologic Deficiency	$68,000,000	$17,000,000	$85,000,000
Seepage & Foundation Problems	$199,000,000	$50,000,000	$249,000,000
Outlet Tunnel Deterioration	$21,000,000	$5,000,000	$26,000,000
Gate Deterioration	$17,000,000	$4,000,000	$21,000,000
Spillway Erosion	$30,000,000	$7,000,000	$37,000,000
Relief Wells	$9,000,000	$2,000,000	$11,000,000
Appurtenant Facilities	$99,000,000	$25,000,000	$124,000,000
Sedimentation	**$250,000,000**	**$62,000,000**	**$312,000,000**
Sedimentation	$250,000,000	$62,000,000	$312,000,000
Water & Sewer Infrastructure	**$1,059,000,000**	**$265,000,000**	**$1,324,000,000**
Wastewater	$685,000,000	$171,000,000	$856,000,000
Water Supply	$374,000,000	$94,000,000	$468,000,000
Acid Mine Drainage	**$187,000,000**	**$47,000,000**	**$234,000,000**
Acid Mine Drainage	$187,000,000	$47,000,000	$234,000,000
Total	**$1,939,000,000**	**$484,000,000**	**$2,423,000,000**

** These are preliminary costs developed by USACE and in-part by supporting state agencies.*

In addition, a major detriment to successful flood management is reduced retention capacity due to sedimentation. Beach City has already lost its conservation pool due to sedimentation, and several other Muskingum lakes are rapidly filling up with sediments. Dredging is the most likely means for restoring the original storage capacities of the lakes. A preliminary cost estimate was prepared to dredge sediments in the lakes in order to restore the lakes' original storage capacities. It is based on a cost of $4 per cubic yard and totals $312 million.

Water quality in the Muskingum River Basin is a pressing concern to the environment and to public welfare. The Ohio Environmental Protection Agency (OEPA) indicates a significant number of the basin's municipalities' water and wastewater infrastructure are in violation of public health criteria and are contributing to degraded water quality. Currently, the Corps administers a Section 594 Program to provide technical and funding assistance to Ohio municipalities for infrastructure projects. A priority for this program will be sites affecting water quality of the Muskingum watershed, especially since these resources will likely be relied upon to meet the future demands for water supply. OEPA data indicates that needed wastewater system repairs and improvements in the Muskingum Basin are estimated at $856 million and needed water supply repairs and improvements are estimated at $468 million.

The U.S. Environmental Protection Agency has determined acid mine drainage (AMD) to be the number one water quality problem in Appalachia. The Ohio Department of Natural Resources (ODNR) estimates that there are more than 180 abandoned mined land sites upstream of the Muskingum reservoirs. The ODNR estimates that it would cost approximately $234 million to remediate these sites and that does not include the purchase of any required real estate but many of the sites are on government lands.

The scope of renewal and revitalization for the Muskingum Basin is robust and multi-faceted. By adding the costs to address each of these water resource problem areas it is estimated it will take several decades and cost more than $2.4 billion to correct the deficiencies in the Muskingum River Basin.

6. Recommendations

It was in the national interest – and in the interest of the state, the region and local communities – to support construction of the Muskingum River Basin system in the 1930s. Now, especially in light of recent national attention to the importance of flood control infrastructure, it is time to reinvest into these resources to preserve, protect and enhance this nationally significant and economically important system. Partnering agencies on the Federal, state and local levels are working to gain the long-term commitment from citizens, landowners, industries and businesses, and from government officials at all levels to extend the life of the valuable and vitally important Muskingum River Basin Flood Control System.

This Muskingum River Basin System Operations Report serves as the initial phase of the process to revitalize the Muskingum Reservoir System. It develops a preliminary plan of action for proceeding with projects under existing Corps authorities, and supports a legislative initiative for a comprehensive study with General Investigations funding. It documents the findings and assesses the current needs in the basin through a multidisciplinary strategy and a multifunctional team. The scope of renewal and revitalization is robust, multi-faceted, and estimated to cost more than $2.4 billion spanning several decades to complete. Before committing this significant amount of funding, the partnering agencies who have assisted in the preparation of this report will be consulted in order to develop a comprehensive, broad-based plan to revitalize the Muskingum Basin. These agencies include, but are not limited to, Federal agencies such as the USACE, USFS, USFWS, USGS and the NRCS, state agencies including the MWCD, OARDC, ODNR, OEPA, OSU, and SWCDs, and local agencies such as the Buckeye Hill RC&D, Crossroads RC&D, and NEFCO. (See Section 1.e. for a list of the participating agencies.)

The next phase would be the detailed study stage in which the Corps of Engineers would undertake a comprehensive assessment to further define and quantify the potential scope of problems and opportunities. Detailed studies to address the needs identified in this report could proceed under existing Corps' authorities with multiple sources of funding - mainly the very limited operations and maintenance funds - or the Corps could await authorization of a comprehensive study before proceeding.

The final phase of the process would be the implementation stage. In this phase, the Corps would implement the program plan of action by proceeding without specific program authorization using existing authorities requiring feasibility reports to Congress on a project-by-project basis, or be directed to implement a comprehensive program following Congressional authorization.

It is our recommendation that the most efficient means to address the revitalization of the Muskingum Basin is through a comprehensive program. A Program Management Plan to guide the next phase of study has been developed and is at Appendix G.