REPORT

ON

FEASIBILITY STUDY ON THE REMOVAL OF BANK AND RIVER BOTTOM SEDIMENTS IN THE MAHONING RIVER

to

U.S. ARMY CORPS OF ENGINEERS
PITTSBURGH DISTRICT

June, 1976

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PRELIMINARY

SYLLABUS

This Feasibility Report examines the characteristics of the bottom sediments and oil-soaked bank material of the Mahoning River, the impact that these polluted materials have on water quality, and various alternatives for reducing their adverse impact. The study concerned itself with the heavily industrialized reach of the Mahoning River from Warren, Ohio to its confluence with the Shenango River at New Castle, Pennsylvania.

The findings of the study show that the sediments in the Mahoning River from River Mile 40.0 (Warren, Ohio) to River Mile 0 (New Castle, Pennsylvania) all violate the U.S. Environmental Protection Agency criteria for polluted sediments. The sediments upstream of Warren at Leavittsburg (River Mile 46.2) were found to contain constituents in concentrations lower than those established by the U.S. EPA for defining polluted sediments. The banks of the Mahoning River from the Republic Steel Plant (River Mile 36.8) in Warren to the low head dam in Lowellville, Ohio (River Mile 13.0) are extensively soaked with oil residues. Despite these conditions, the polluted sediments and bank materials exert by themselves a relatively minor impact on water quality, assuming worst case conditions.

The most significant adverse condition, as a result of sludge, occurs during the winter low flow, in the pool created by the dam at Lowellville. Dissolved oxygen criteria would be violated by the sludges acting alone at this pool, in the absence of other point and non-point discharges.

The sediments reflect the quality of point and non-point discharges. If the sediments were of a quality similar to those at Leavittsburg, they would have a negligible impact on the Mahoning's dissolved oxygen during critical low flow periods. No alternative plan for sediment control can provide major improvement over existing conditions in the long term, unless urban point and non-point discharges are significantly improved.

A number of alternative plans for sediment removal or control were evaluated, ranging from "No Action" to complete removal of all polluted material.

In addition, the study considered the beneficial impact of the removal of three low-head dams which are no longer in use for their original purpose. These dams create pool areas which accumulate sediment materials.

The evaluation of the alternatives included cost-effectiveness comparisons and environmental consequences. The recommended alternative (Alternative 5) includes the dredging of sediments from the pool at Lowellville (R.M. 13.0); partial dewatering of the material removed; deposit of the material in a sanitary landfill under controlled conditions; and demolition of the low-head dams at River Miles 6.9, 13.0 and 21.1. The cost of the recommended alternative is estimated at $159,000.

Implementation of the recommended plan will result in some improvement in Mahoning River water quality. The report emphasizes, however, that major improvement in water quality depends upon control of point and non-point sources of pollution discharges, and that implementation of the plan recommended herein cannot achieve maximum benefit in the absence of such controls.

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I. INTRODUCTION

A. SCOPE OF THE PROJECT

In connection with the overall studies of the Beaver River Basin, the Pittsburgh District, Corps of Engineers, commissioned the environmental engineering firm of Havens and Emerson, Ltd. to study the following aspects of the Mahoning River: (1) the characteristics of the sludges and sediments deposited on the bottom and along the banks of the river; (2) the impact of these deposits upon river water quality; and (3) the feasible alternatives for the elimination of this source of pollution. The portion of the Mahoning River studied consists of the reach from the Leavittsburg Dam (River Mile 46.2) downstream to its confluence with the Shenango River at New Castle, Pennsylvania (River Mile 0.0).

B. AUTHORIZATION

The study of the Mahoning River sediment and bank pollution problems stems from a resolution adopted 11 April 1974 by the Committee on Public Works of the United States House of Representatives. The House Public Works Committee resolution states:

> "RESOLVED BY THE COMMITTEE ON PUBLIC WORKS OF THE HOUSE OF REPRESENTATIVES, United States, that the Board of Engineers for Rivers and Harbors is hereby requested to review the report of the Chief of Engineers on the comprehensive flood control plan for the Ohio and Lower Mississippi Rivers published as Flood Control Committee Document No. 1, 75th Congress, and other pertinent reports, with a view toward determining if any modifications of the present comprehensive plan for flood control and other purposes are advisable at this time with reference to environmental improvements relating to water quality in the Mahoning River, and with particular reference to dredging and offsite disposal of river bottom sludges."

C. DESCRIPTION OF THE STUDY AREA

The Mahoning River drains 1133 square miles in the western and northern portion of the Beaver River Basin. The Mahoning varies in width from about 50 feet to about 300 feet, and in its length of about 108 miles, it has an average slope of about 4.4 feet per mile. It has its source in Columbiana County, Ohio, and flows generally northeast from Alliance in Stark County to near the City of Warren in Trumbull

County, being impounded along the way by the Berlin-Milton Reservoir system. The river then flows generally southeast from Warren, through Trumbull and Mahoning Counties, to where it joins with the Shenango River at New Castle, Pennsylvania. Principle tributaries of the Mahoning River include Hickory Run and Yellow, Mill, Crab, Meander, Mosquito, Duck, Eagle, West Branch, Kale, Deer, and Beech Creeks. The Mahoning River is a highly flow-regulated stream; five major reservoirs have been constructed within the watershed. These reservoirs are listed in Table 1. Figure 1 shows the drainage basin for the river and the locations of the major reservoirs.

This study is concerned with the lower 46 miles of the river from the Leavittsburg Dam (R.M. 46.2) to the confluence of the Mahoning with the Shenango River at New Castle, Pennsylvania. In addition to the major upstream reservoirs, the main stem of the Mahoning has 12 low head dams originally constructed to provide pools for industrial water supply. The locations of these low head dams are shown in Figure 2.

The river from Warren, Ohio to nearly the Ohio - Pennsylvania state line is dominated by industrial development. The majority of the land along both sides of the river is owned by steel mills or railroads. The major current use of the Mahoning River in the reach considered is industrial water supply and waste assimilation. Many municipal and industrial waste treatment plants discharge to the river resulting in serious water quality problems in the river. The main pollutants in the lower Mahoning River are: heat, oxygen consuming materials, acids, taste and odor producing substances, sulfates, oil and grease, settleable solids, metals, bacteria, and phenols.

There is virtually no public use of the Mahoning River for recreation pursuits within the study area. There are approximately four city parks located on the banks of the Mahoning between Warren and New Castle, but these do not use the River for recreational activities. The City of Beaver Falls uses the Beaver River as its source of potable water; taste and odor problems are common as a result of pollution of the Mahoning River.

D. ECONOMIC, SOCIAL, AND ENVIRONMENTAL RESOURCES OF THE STUDY AREA

Battelle Columbus Laboratories was commissioned to prepare a study of present and future economic, social, and environmental conditions of the Beaver River Basin. The final report titled "Economic, Social, and Environmental Profile - Beaver River Basin, Ohio and Pennsylvania" was completed in January, 1975 and includes all relevant baseline information for the Mahoning River. A brief summary of the content of the report follows.

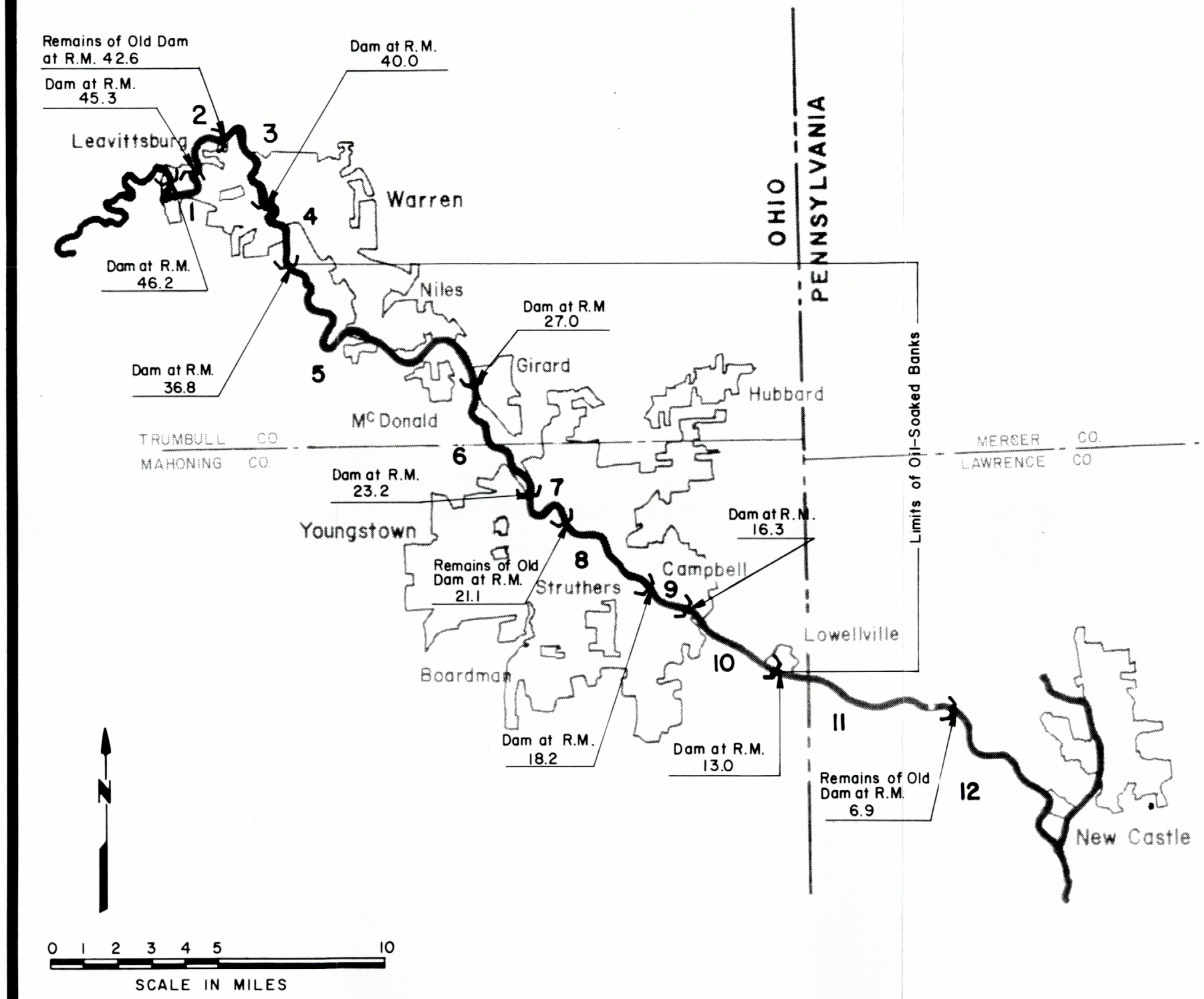


FIGURE-2
REACHES AND DAMS

MAHONING RIVER STUDY
DEPARTMENT OF THE ARMY
PITTSBURGH DISTRICT, CORPS OF ENGINEERS

1. Study Background

In recognition of the substantial effect which public works projects and other public programs frequently have on economic, social, and environmental conditions in and around the project or program area, the Federal government has enacted laws to require careful assessment of these effects before projects or programs are undertaken. The National Environmental Policy Act of 1969 required that environmental impact statements be prepared for all projects or programs supported by Federal funds or activities. Supplemental to this law, Section 122 of the River and Harbor and Flood Control Act of 1970 (PL 91-611) specified that consideration of all possible adverse economic, social, and environmental effects, including at least 17 specific types of effects, be included as primary considerations in decisions made regarding proposed projects and programs. The Corps of Engineers has developed a set of guidelines (Information Supplement No. 1 to Section 122 Guidelines -- ER 1105-2-105, 15 December, 1972) to ensure that the requirements of Section 122 are satisfied. At a minimum, these guidelines require an assessment of all relevant conditions at the time of proposed project or program initiation, a projection of these conditions -- assuming no project will be built -- for a period of time equivalent to the anticipated useful life of any proposed project, and a projection of the conditions through the same period of time in the event that one or more projects are undertaken.

The development of economic, social, and environmental profiles for existing and projected future conditions is a first step in the Corps' study. It was undertaken in this study with specific intent to minimize field data collection, relying almost entirely upon the use of available secondary information as the basis of the necessary analyses.

2. Study Objectives

The general purpose of the Battelle report was to establish a relevant planning setting and a framework for analysis to assist the Pittsburgh District in identifying the needs and problems in the Beaver River Basin. More specific objectives of the effort were as follows:

- To describe existing economic, social, and environmental conditions in the Beaver River Basin in a systematic and comprehensive manner as a basis for water related planning.

- To project economic, social, and environmental conditions in the Beaver River Basin as a basis for assessment of future water related program and/or project needs in the basin.

- To assess water related needs derived from existing and projected conditions in the Beaver River Basin.

The scope of the effort includes

- Profiles of existing social, economic, and environmental conditions in the Beaver River Basin.

- Projections of the "without project" conditions in the Basin for intervals up to 100 years in the future (2070) from the baseline data (1970).

- An analysis of existing and future water related needs and problems in the basin.

II. PROBLEM IDENTIFICATION

A. GENERAL

The five major upstream reservoirs result in significant reduction of flood flows, and the twelve low head dams produce a series of pools from Warren to the Ohio-Pennsylvania state line. The combined effects of these structures is to reduce peak flow velocity in the stream, which encourages settling of both organic and inorganic solids, originating from large municipal and industrial discharges as well as rural and urban non-point sources.

Pittsburgh District personnel surveyed the Mahoning River in April, 1975. Sludge deposits and oil-soaked banks were located and the approximate depths were determined. The river was again surveyed in October, 1975 by Havens and Emerson personnel.

The oil-soaked banks first appeared immediately downstream of the Republic Steel dam in Warren at River Mile 36.8. The river had both an oil sheen and droplets of oil floating on the surface. The oil-soaked banks and the oil sheen extended from the Republic Steel dam downstream to the Lowellville dam at River Mile 13.0. Numerous steel mill discharges were observed containing visible oil. Downstream of the Lowellville dam only a few scattered oil deposits were seen and the oil sheen disappeared. Attempts to step from the canoe to land at several locations upstream of Lowellville resulted in sinking up to 24 inches in oil saturated silt.

Despite the heavily industrialized nature of the Mahoning, and the sludges and oil-soaked banks, the majority of its stream banks are lined with trees and low vegetation. The extensive oil-soaked banks have numerous sycamore, red maple, silver maple, and poplar trees, as well as various shrubs rooted in the material. Obviously the oily material is not toxic to riverside vegetation.

Several species of ducks, at least two great blue herons, and a number of belted kingfishers which were fishing were observed over the 46 miles of the river. Two small gizzard shad were seen, one living and one dead, in the pool behind the Lowellville dam. No information exists to whether fish are permanent inhabitants of the river. It is possible that fish enter the Mahoning from tributary streams or are washed downstream from upstream reservoirs. Although a biological survey was not part of this study, these casual observations of fish and fishing birdlife indicate that the Mahoning does support some aquatic populations.

The following sections discuss general water quality characteristics, the quantities of sludges and oil-soaked bank material, and the impact of these materials on water quality.

B. FLOW CHARACTERISTICS

1. Historic

Flows in the lower 46 miles of the Mahoning River are influenced by natural precipitation events, upstream operation of the five major reservoirs, municipal wastewater releases, and consumptive industrial river water usages. In addition to the USGS gage station at Leavittsburg (03094000), which defines the beginning of the stream reach of interest, permanent main stem flow monitoring points are also found at Youngstown (03098000) and Lowellville (03099500). These stations are located on Figure 3; the upstream drainage of each is 575, 898, and 1,073 square miles, respectively.

Table 2 summarizes the flow characteristics at each of these stations for selected hydraulic occurrences for the period of record since the construction of the Michael J. Kirwin Dam and Reservoir. It is noted here that the period between 1968 and 1973 experienced a higher flow than normal. The normal low period in the watershed is experienced in the July through October (JASO) time period when ambient temperatures are the highest. Conversely, the normal high flow period encompasses the February through May (FMAM) time period when ambient temperatures steadily increase from their winter minimums. A brief examination of these records shows little variation in the measured runoff coefficient for the flow regimes examined. The Youngstown gage picks up the upstream wastewater releases from Warren, Niles, Girard and McDonald. The additional discharges from Youngstown and Campbell are introduced upstream of the Lowellville gage. Upstream storage at the reservoirs and wastewater releases are seen to have relatively little impact upon the overall runoff coefficient measured at the gaging stations under current conditions. In contrast, in the five years prior to 1968 and the completion of the Michael J. Kirwan Dam and Reservoir, the minimum monthly flow runoff coefficient (November, 1963) was 0.19 cfs/SM at Leavittsburg and 0.31 and 0.27 cfs/SM at Youngstown and Lowellville.

2. Projected

The Ohio Environmental Protection Agency pursuant to the requirements of Section 303c of Public Law 92-500, define the critical low flow period as the "Annual minimum 7 day average flow that has a recurrence period of once in ten years". This definition is used for

TABLE 1

MAJOR RESERVOIRS - MAHONING RIVER BASIN

Reservoir	Year Completed	Drainage Area (sq. miles)	Total Storage Capacity (acre-ft.)	Owner or Operator
Milton	1917	276	29,770	City of Youngstown
Meander Creek	1931	83	32,400	Mahoning Valley Sanitary District
Berlin	1943	249	91,200	Corps of Engineers
Mosquito Creek	1944	97	104,100	Corps of Engineers
Michael J. Kirwan Dam and Reservoir	1966	80	78,700	Corps of Engineers
		Total	336,170	

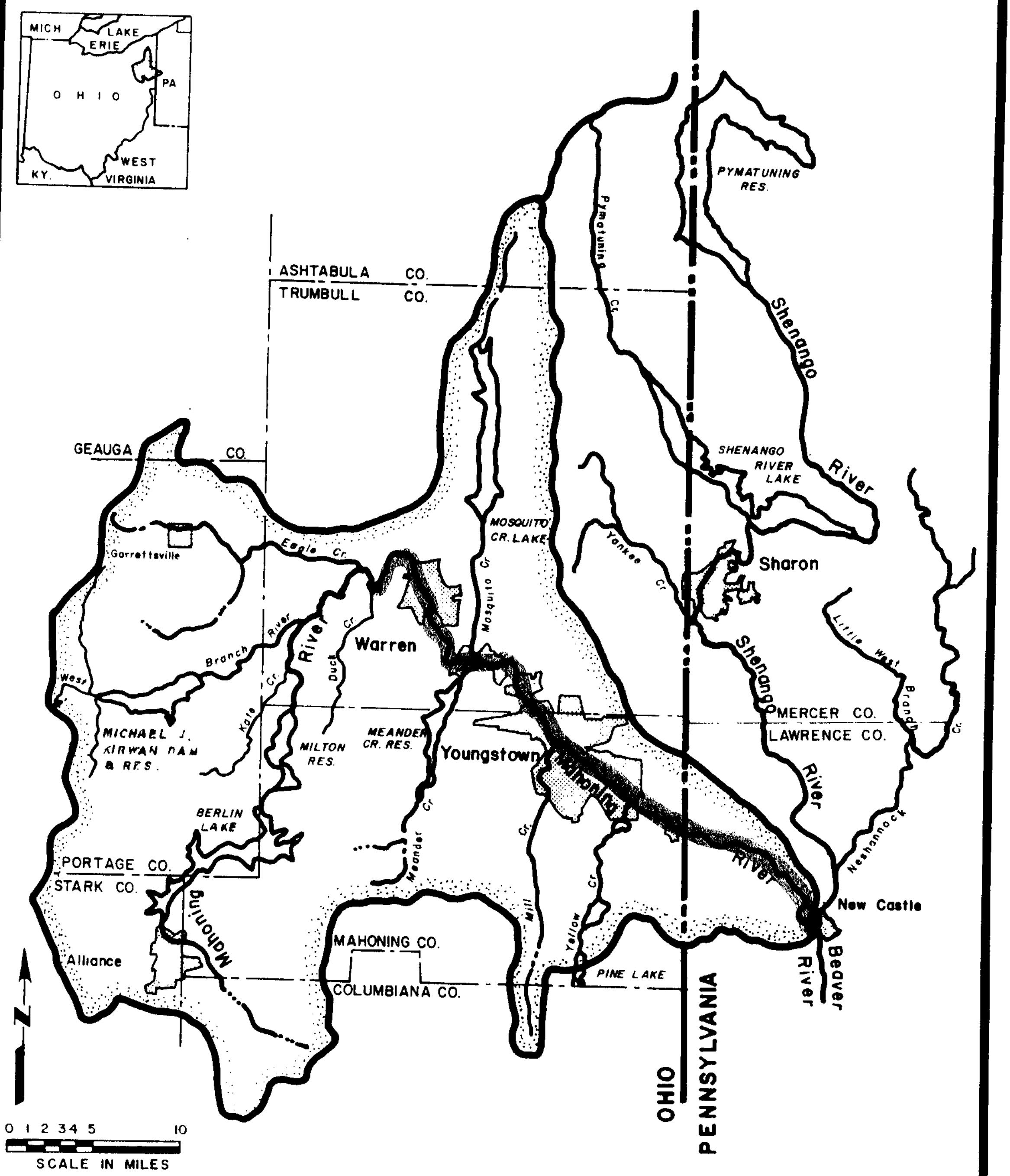


FIGURE - I

DRAINAGE BASIN

MAHONING RIVER STUDY
DEPARTMENT OF THE ARMY
PITTSBURGH DISTRICT, CORPS OF ENGINEERS

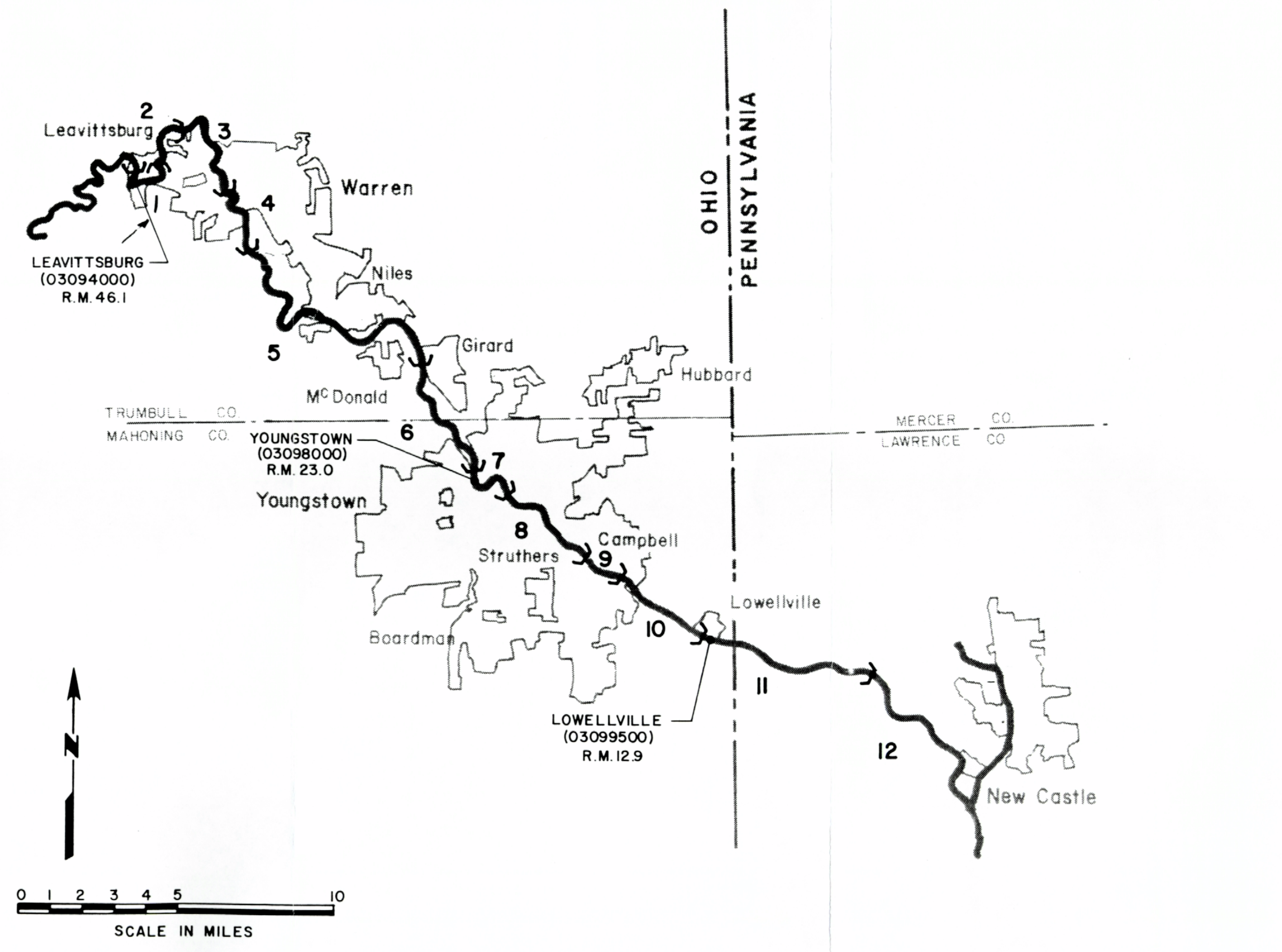


FIGURE- 3
USGS GAGING STATIONS

MAHONING RIVER STUDY
DEPARTMENT OF THE ARMY
PITTSBURGH DISTRICT, CORPS OF ENGINEERS

TABLE 2
USGS FLOW RECORD SUMMARY
(October, 1968 Through September, 1973)
and as noted

PARAMETER	MAHONING RIVER AT		
	LEAVITTSBURG	YOUNGSTOWN	LOWELLVILLE
PERIOD OF RECORD	1940 TO DATE	1921 TO DATE	1942 TO DATE
Record Maximum*			
cfs	20,300	17,600	21,000
cfs/SM	35.3	19.6	19.5
Maximum Month			
(Apr 1972) cfs	1,648	2,535	2,999
cfs/SM	2.9	2.8	2.8
Avg. Max. Month			
(March) cfs	1,042	1,717	2,007
cfs/SM	1.8	1.9	1.9
Avg. FMAM			
cfs	849	1,388	1,580
cfs/SM	1.5	1.5	1.5
Avg. Annual			
cfs	590	860	1,086
cfs/SM	1.0	0.96	1.01
Avg. JASO			
cfs	359	514	637
cfs/SM	0.62	0.57	0.59
Avg. Min. Month			
(October) cfs	278	393	504
cfs/SM	0.48	0.44	0.46
Minimum Month			
(Nov 1971) cfs	186	274	332
cfs/SM	0.32	0.31	0.30
Record Minimum*			
cfs	55	28	125
cfs/SM	0.10	0.03	0.12

cfs/SM = cubic feet per second per square mile
*Period of Record
Note: The period of October, 1968 through September, 1973 was a wet period as compared to the historic average.

most streams in establishing waste load allocations for meeting water quality standards. In the case of the highly flow-regulated Mahoning River, the OEPA has defined two critical low flow regimes. These regimes are summarized in Table 3. Inherent in these definitions are the guaranteed minimum flow releases from the Watershed's reservoir complex. Currently, the Pittsburgh District is scheduled to maintain a minimum flow schedule of 145 cfs at Leavittsburg from the middle of November to the middle of March. A minimum Leavittsburg flow is maintained at 310 cfs throughout June, July and August. The minimum flow schedule at Youngstown corresponds to about 225 cfs from November through March with a peak flow of about 480 cfs during the last fifteen days of July.

A summary of the chronological monthly flow variation at the gages is shown in Figure 4. Superimposed upon this figure are the critical low flows sought by the Ohio Environmental Protection Agency. As can be seen from Figure 4, the OEPA winter low flows are easily achieved. This is not the case, however, for the OEPA summer low flows; for in the JASO period of elevated ambient temperature, 45 percent (or nine of twenty average monthly flows) were less than the projected critical low flows sought by the Ohio Environmental Protection Agency. The implication is clear that there is no firm record that indicates that the sought OEPA minimums can be achieved throughout the JASO period. Reservoir operation has been reviewed and it has been determined that the reservoirs are providing the maximum flow releases possible. It is suggested that Ohio EPA reevaluate its low flow load allocations to adjust to the flows which can be provided.

For the purposes of this report, the flows as presented in Table 3 have been used for assessing water quality impacts because the water quality standards are based on these OEPA low flows.

C. STREAM WATER QUALITY CHARACTERISTICS

1. Water Quality Standards

Ohio water quality standards for the Mahoning are confused at the present time. The Ohio Environmental Protection Agency issued standards for the Mahoning River in 1972, which subsequently resulted in a Court suit challenging the new standards. In 1975, Ohio EPA proposed a new set of less stringent water quality standards, which were designed to meet the Commonwealth of Pennsylvania quality standards at the state line. These new standards have not been approved by the U.S. EPA. The Ohio EPA is in the process of developing yet another set of standards which would be more acceptable to U.S. EPA.

TABLE 3

OHIO EPA MAHONING RIVER CRITICAL LOW FLOWS, CFS
(NEAREST CFS)

LOCATION	RIVER MILE	SUMMER FLOW INCREMENT	SUMMER CUMULATIVE FLOW	WINTER FLOW INCREMENT	WINTER CUMULATIVE FLOW
Leavittsburg Gage	46.2	315	315 (0.55)	145	145 (0.25)
Warren Wastewater Treatment Plant	35.8	25	340	25	170
Mosquito Creek	31.3	100	440	43	213
Meander Creek	30.9	8	448	8	221
Niles, Girard and McDonald Wastewater Treatment Plants	29.5 to 25.7	16	464	16	237
Youngstown Gage	23.0	-	464 (0.52)	-	237 (0.26)
Mill Creek	22.2	15	479	18	255
Crab Creek	19.9	4	483	6	261
Youngstown Wastewater Treatment Plant	19.8	62	545	62	323
Campbell South Wastewater Treatment Plant	16.2	13	558	13	336
Lowellville Gage	12.9	-	558 (0.52)	-	336 (0.31)
Lowellville	12.6	1	559	1	337

(   ) = cfs/SM

Note: These data were provided by the Ohio Environmental Protection Agency and are used by OEPA for wastewater load allocations.

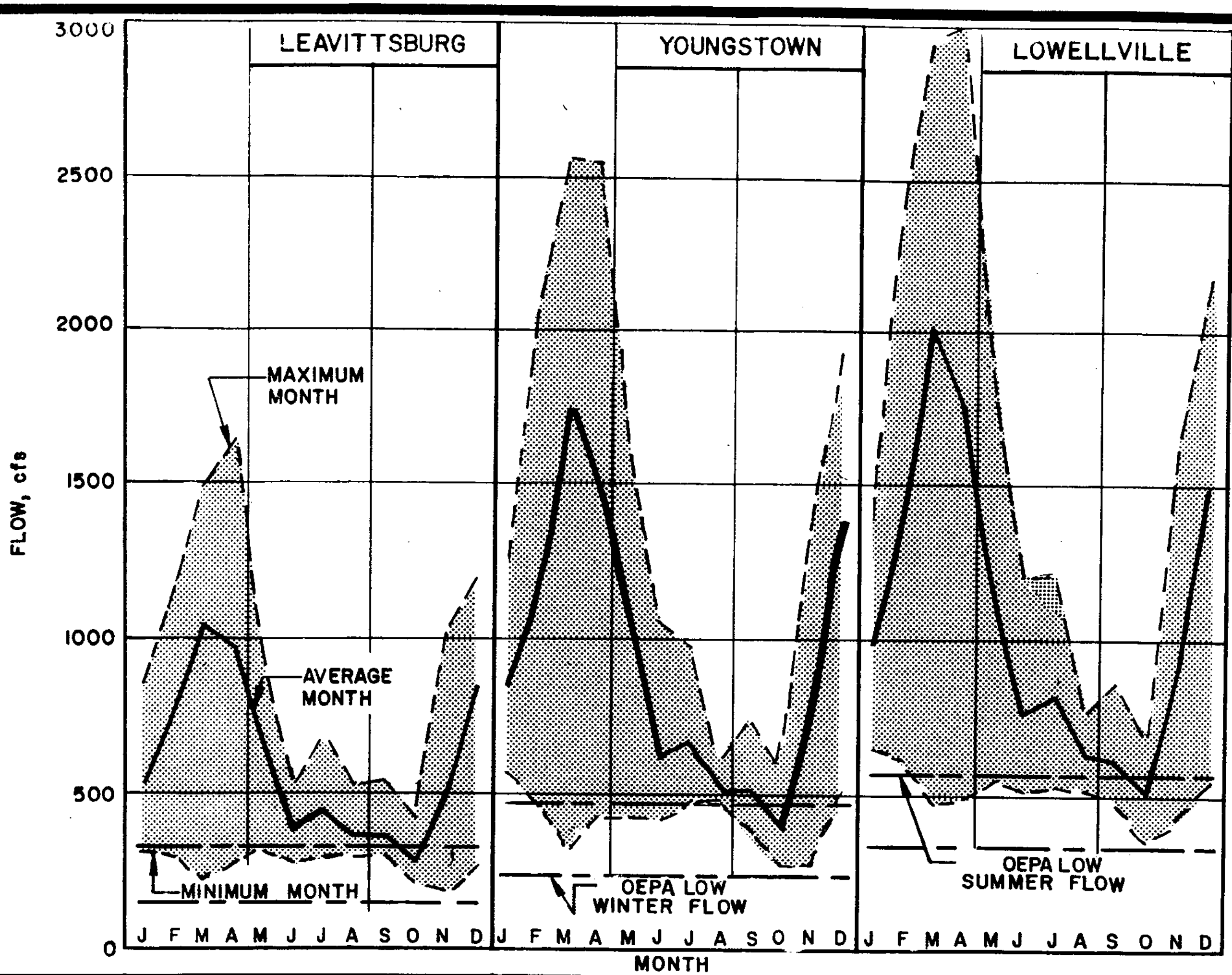


FIGURE - 4

CHRONOLOGICAL MONTHLY FLOW VARIATION OF THE MAHONING RIVER
(OCTOBER, 1968 THROUGH SEPTEMBER, 1973)

MAHONING RIVER STUDY
DEPARTMENT OF THE ARMY
PITTSBURGH DISTRICT, CORPS OF ENGINEERS

Table A-1 in Appendix A presents the General Ohio Warm Water Fisheries Standards, the Ohio Mahoning River - 1972 standards, the Proposed Ohio Mahoning River Standards, and the Pennsylvania Water Quality Standards for comparison. One thing that appears to be certain is that the standards ultimately adopted for the Mahoning in Ohio will require that the river quality meet Pennsylvania's water quality standards at the state line.

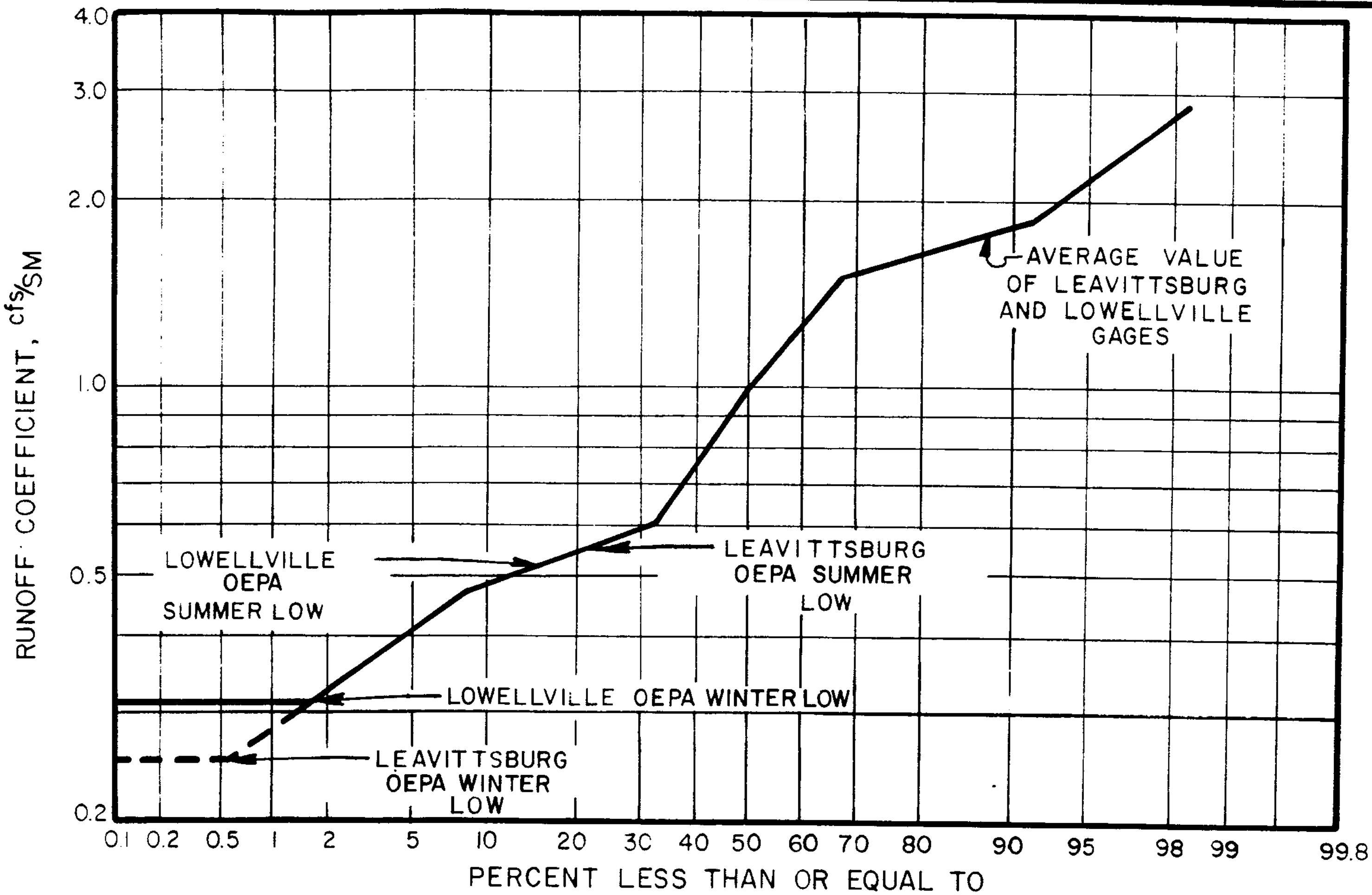
2. Water Quality

The USGS maintains and reports water quality information at the Leavittsburg Gage and in the vicinity of the Lowellville Gage (downstream of Lowellville near the Ohio-Pennsylvania State Line). Water quality analyses have been reported at these two stations since 1967. The data from these two stations can be used to define the degradation of the Mahoning as it flows through the Warren-Youngstown urban corridor towards its confluence with the Shenango River.

Water quality characteristics are, of course, flow dependent. In order to address the significance of a given measured parameter, it is important to know the corresponding flow regime and its frequency of occurrence. Thus, Figure 5 was created from the average runoff coefficients developed in the previous discussion of Mahoning River flow characteristics. From this figure, flow occurrence intervals of 90, 50 and 10 percent less than or equal to were selected. These, in turn, yield the following approximate runoff coefficients and flows:

Percent of Time Less Than or Equal to	Runoff Coefficient cfs/SM	Flow at: Leavittsburg cfs	Flow at: Lowellville cfs
90	1.8	1,035	1,930
50	1.0	575	1,075
10	0.48	275	515

Figure 6 illustrates the river's water quality as a function of the above flow regimes for the parameters addressed in the Pennsylvania Water Quality Standards. Maximum, median and minimum measurements are given with the applicable water quality standard indicated by the dashed line. A review of these data indicated that violation of the lower level pH limit is most likely to occur when flows drop below the annual average. The pH values plotted represent daily averages; daily extremes were recorded below the 6 standard. The heat load introduced into the Mahoning is readily observable with the upstream Leavittsburg and downstream Lowellville temperature data. Ohio's industries cause the Mahoning's temperature to exceed both summer and winter limits.



NOTE: OCTOBER, 1968 THRU SEPTMBER, 1973 WAS A WET PERIOD AS COMPARED TO THE HISTORIC AVERAGE

FIGURE - 5
PROBABILITY OCCURRENCE OF AVERAGE RUNOFF COEFFICIENT

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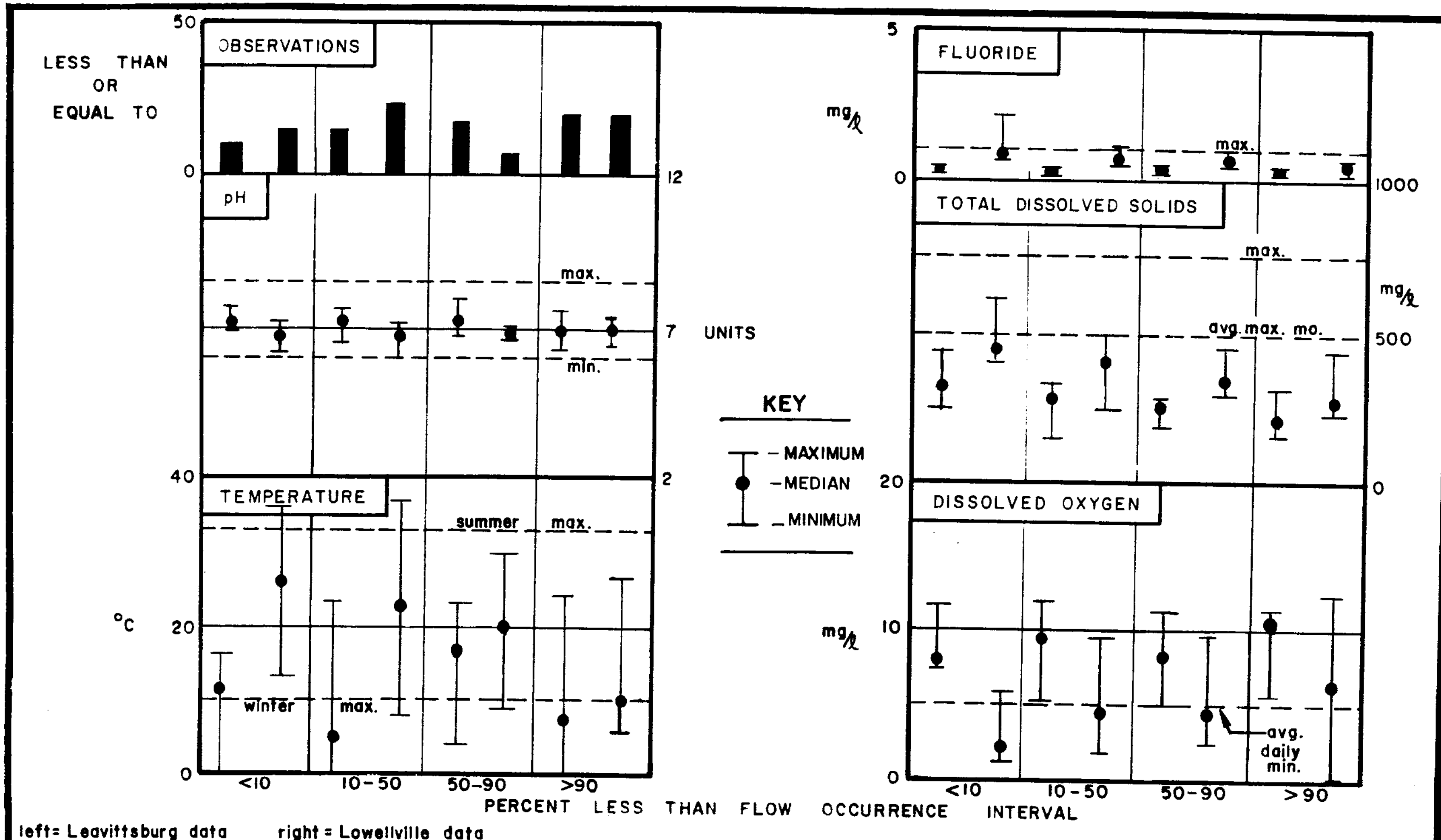

FIGURE - 6
MAHONING RIVER WATER QUALITY
(USGS RECORDS, 1968 THROUGH 1973)
(PENNSYLVANIA WATER QUALITY STANDARDS)

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Fluoride concentrations in excess of the 1.0 mg/l limit are also observed at Lowellville when stream flows drop below the average annual condition. Total dissolved solids values at Lowellville only exceed the allowable maximum monthly concentration of 500 mg/l when flows are less than or equal to ten per cent of the average monthly values. Dissolved oxygen violations at Lowellville are most striking as depressions below the 5 mg/l standard are observed at each flow regime examined. Median dissolved oxygen values remain below 5 mg/l until flows exceed 90 percent of the monthly averages.

The turbidity data (1967 through 1973) collected at the same two gaging stations can be used to roughly quantify what flow regimes cause an apparent resuspension of the accumulated bottom deposits. Figure 7 illustrates the turbidity flow relationships. The Leavittsburg data show a reasonably constant turbidity value until stream flows are in excess of the summer minimum. Turbidity values in excess of ten units are not reported for this station until stream flows exceed 800 cfs. In contrast, the Lowellville turbidity data deviates from the background conditions observed at Leavittsburg once flows in excess of the winter minimum are encountered. At Lowellville, flow regimes between the winter and summer minimums appear to cause a sharp rise in turbidity which may reflect resuspension of the bottom deposits. Obviously, the Lowellville data may also reflect the presence of other point and non-point pollution sources. It is significant to note, however, that once the Lowellville flow exceeds the OEPA summer minimum, recorded turbidity values never drop below 15 units. It would appear from this limited data that sediment resuspension is of no concern when stream flows decline below the OEPA winter minimum. Historically, since the completion of the Michael J. Kirwan Dam and Reservoir, stream flows have declined below this limit approximately 20 percent of the time. Conversely, it would appear that in-stream deposition and resuspension of settleable solids could be substantially minimized by maintaining flows at or above the projected summer minimum. The existing reservoir system does not permit any increased augmentation above the current reservoir release schedule.

Figure 8 was prepared using the projected nominal turbidity values from the previous figure with the runoff coefficient to obtain a turbidity yield coefficient. Its purpose is to allow a direct comparison of the turbidity yield coefficients at each monitoring point at the same statistical flow regime. For reference purposes, the actual flow experienced at each monitoring point for each statistical flow occurrence is also presented. It should be noted here that turbidity and suspended solids measurements are not necessarily directly proportional nor com-

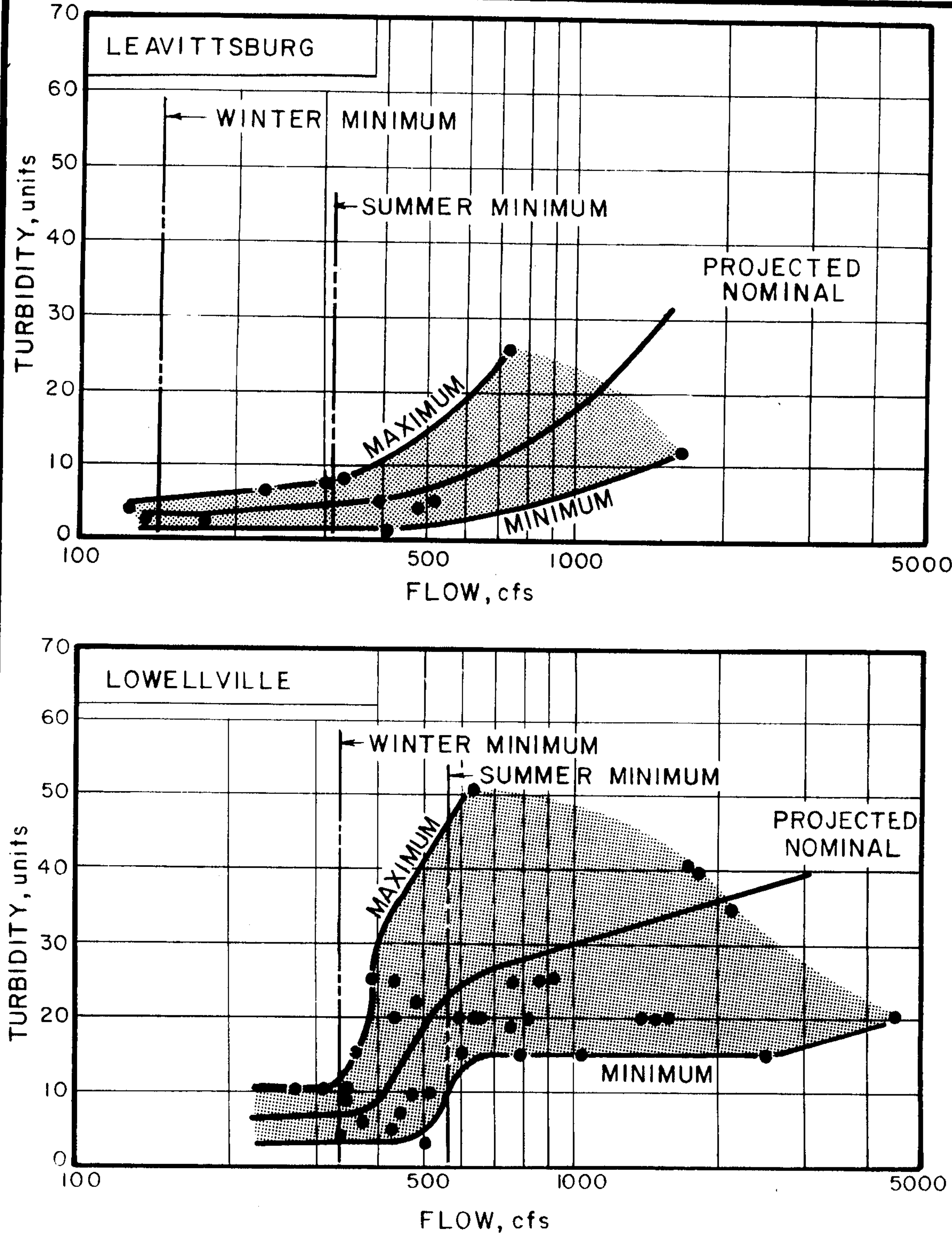

FIGURE - 7
TURBIDITY VS. FLOW
(U.S.G.S. RECORDS 1967 THROUGH 1973)
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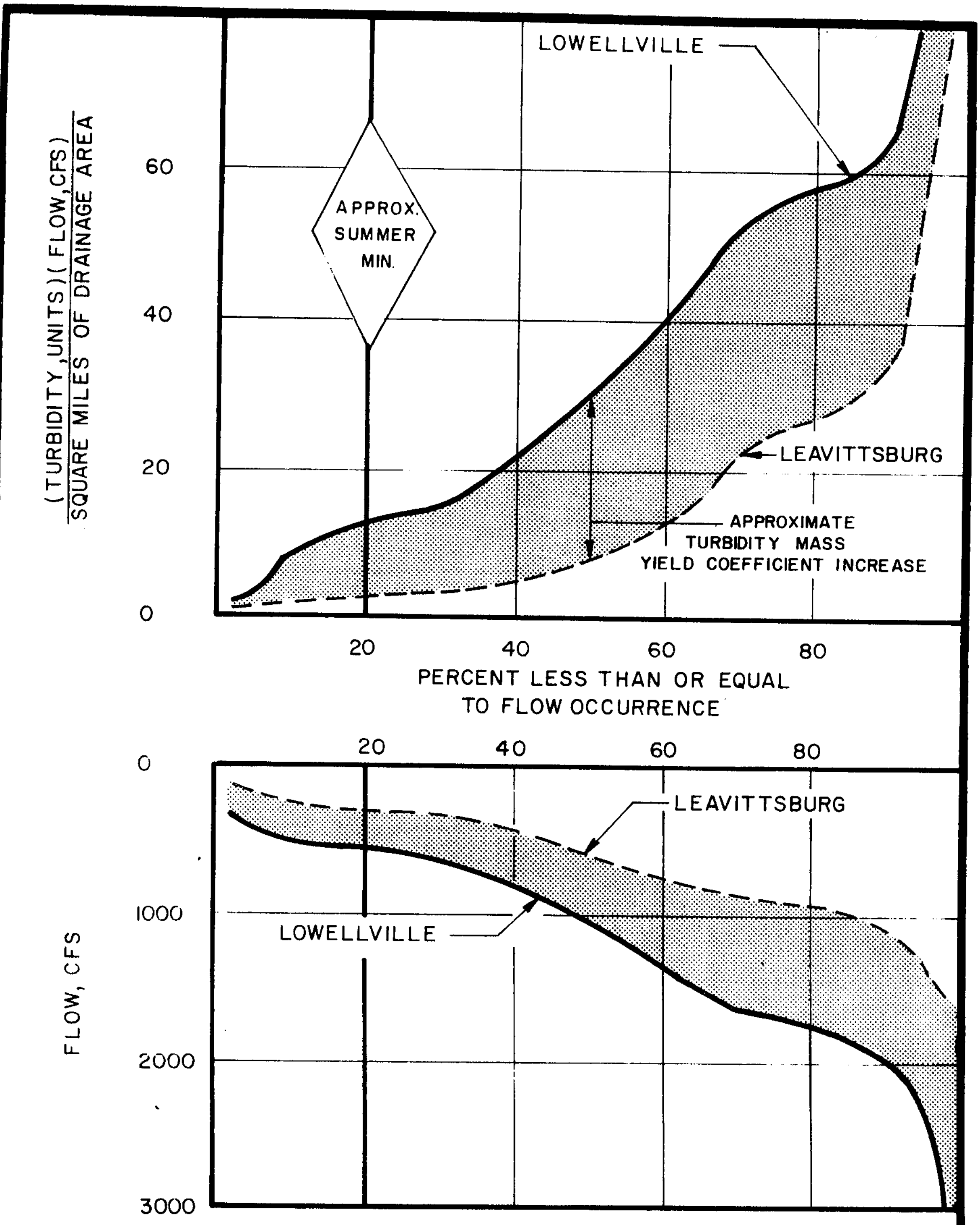

FIGURE - 8

TURBIDITY YIELD COEFFICIENT AND STREAM FLOWS
VS
PERCENT FLOW OCCURRENCE

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parable from station to station. The lack of concurrent turbidity and suspended solids analyses forces such a generality as a last resort when there are no other alternatives available. As can be seen in this figure, turbidity yields remain substantially different throughout the 10 to 90 percent flow occurrence interval. Above and below this range, measured values at Lowellville and Leavittsburg tend to approach one another. The difference between the two stations in the 10 to 90 percent flow occurrence interval reflects the combined impact of sediment and bank scour, point wastewater sources, and the urban runoff developed along the river.

The Mahoning River from Leavittsburg to Lowellville has been the subject of numerous water quality surveys. One of the most extensive was recently conducted during an intensive three-day effort (February 11 - 14, 1975) by the U.S. Environmental Protection Agency. Flows at the Leavittsburg, Youngstown, and Lowellville Gages averaged 840, 1,060, and 1,280 cfs, respectively. These flows are typically exceeded only 35 to 40 percent of the time. Thus, it is likely that the combination of high flows with the cold February temperatures reflect the river's water quality in a far more favorable light than is typical. The average water quality analyses during this survey are summarized in Table A-2 in Appendix A. Figure 9 shows the locations of the major municipal and industrial dischargers to the Mahoning River.

It is interesting to note that the water at the upstream end of the study area already carries copper and phenol concentrations in excess of the 0.01 mg/l Ohio Water quality standard. The river receives few discharges between River Mile 46.2 and River Mile 37.7. Examination of the water quality data in Table A-2 shows a progressive increase in pollutant concentration from River Mile 37.7 to approximately River Mile 16.0. This 22 mile stretch of the river receives the most significant pollutant load from a combination of municipal and industrial dischargers of any section of the river. At River Mile 16.0, the Mahoning River exhibits quality characteristics which are in clear violation of the general Ohio Water Quality Standards for cyanide, phenol, copper, and zinc.

The final 16.3 miles of the Mahoning receives the relatively small municipal discharges from Campbell, Struthers and Lowellville. In this particular stretch of the river, the water quality of Yellow Creek stands out for its excellent characteristics except for copper concentrations.

As the river flows into Pennsylvania at River Mile 11.8, (Table A-2, Sheet 9/9), it continues to carry concentrations of cyanide, phenol,

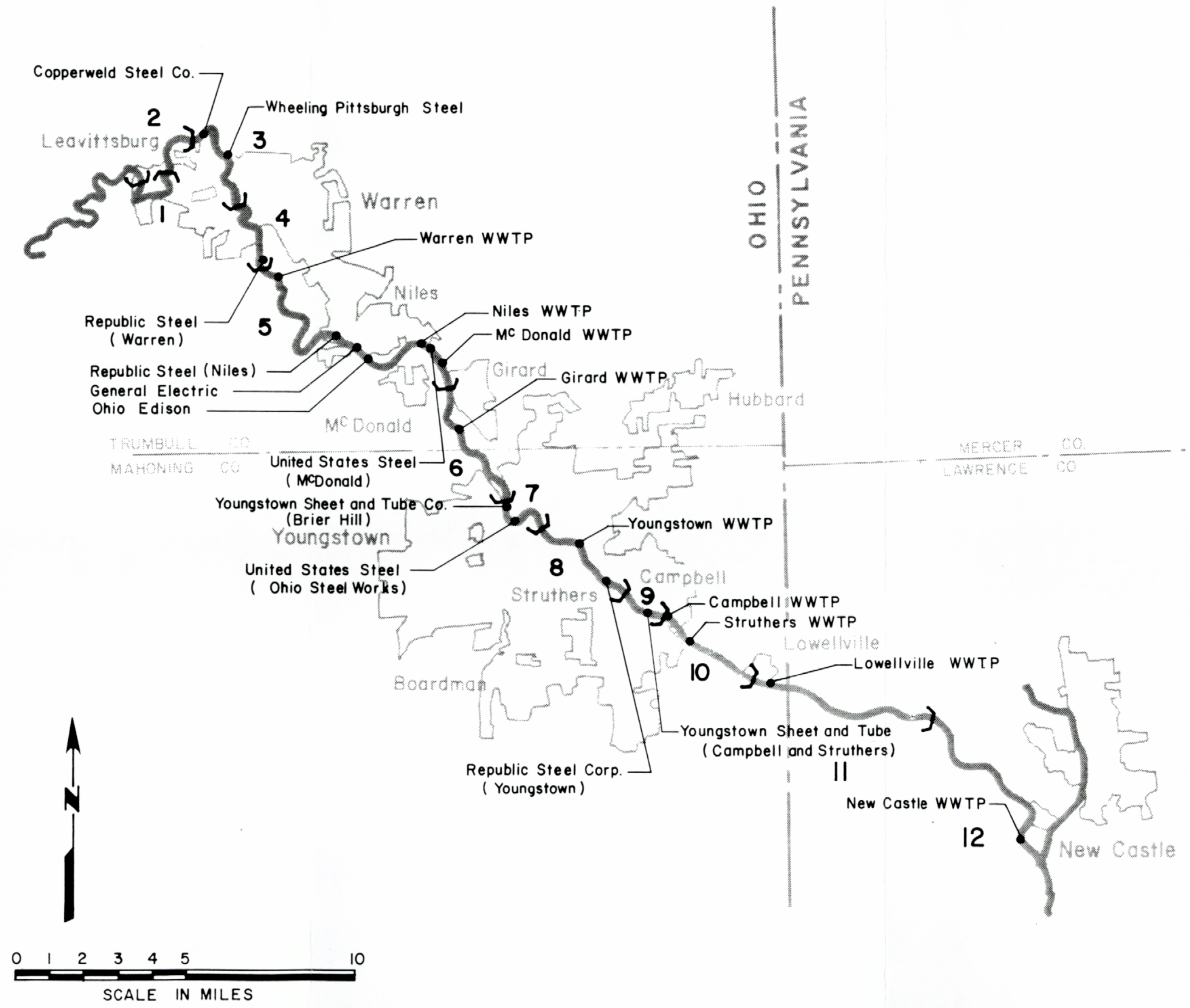

FIGURE-9
MAJOR INDUSTRIAL AND MUNICIPAL DISCHARGES

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copper and zinc well in excess of the water quality standards of both states.

Unfortunately, the EPA sampling run in 1975 did not analyze for oil and grease. However, as part of the proposed NPDES permit program, EPA sampled and analyzed the discharges from the major industries in 1973. In addition, the industries submitted their analysis of oil and grease as part of the permit application. These data are contained in Table A-3, Appendix A. As seen in this table, the total pounds per day of oil and grease discharged to the river is between 70,000 and 110,000.

D. AQUATIC ORGANISMS

Much of the substrate of the Mahoning River is composed of sand, gravel, rock and rubble. Sludge deposits are generally located along the river banks, behind low-head dams, and in slackwater areas. In a clean water situation, one would expect to find a great diversity of organisms inhabiting the rock and gravel stream bed areas. Examination of the rocks and rubble downstream of Warren will generally only uncover the pollution tolerant air-breathing Physa snails.

A survey of the benthic organisms of the Mahoning River from River Mile 33.8 (Niles, Ohio) to River Mile 1.8 (New Castle, Pennsylvania) was conducted by the U.S. Environmental Protection Agency in March, 1975. A benthic sample was also collected by U.S. EPA at River Mile 46.1 (Leavittsburg, Ohio) in May, 1975. The results of this survey are shown in Table 4.

Examination of Table 4 shows that only at Leavittsburg does a fairly good diversity of benthic organisms exist. At the remaining stations, only the pollution tolerant sludge worms, leeches and air-breathing snails are found.

E. ACCUMULATION OF SLUDGE BETWEEN 1962 AND 1975

The Pittsburgh District determined the cross section of the Mahoning River in 11 separate areas in 1962. In each of these areas, (ranging from River Mile 4 to River Mile 40), 3 to 7 individual cross sections were determined. In an effort to examine the change in sediment deposits since 1962, cross sections were again determined in these same areas in 1975. Since the exact zero points of the 1962 cross sections were not known, a comparison of the 1962 and 1975 cross sections can only be approximated. However, the data do give good indications of change in deposits, since the surveyors in both 1962 and 1975 were given explicit

TABLE 4

BENTHIC ORGANISMS

Numbers/Sq. Meter

	Leavittsburg	Niles-West Park Ave	Niles-Belmont Ave	Youngstown Division St	Struthers Bridge St	Campbell Republic Steel Penn Central	Struthers PL & ERR	Lowellville Washington St.	Edinburg Rt 224	New Castle Penn Central Railroad
River Mile	46.1	33.8	30.8	24.0	22.9	18.0	16.0	12.9	7.0	1.8
Substrate	Sand & Gravel	Fly Ash, Sand, Oily Sludge	Sewage, Sludge & Oily Sludge	Sand, Black Oily Sludge, Ash	Black Oily Sludge	Black Oily Sludge	Black Oily Sludge	Black Oily Sludge	Sand & Oily Sludge	Black Oily Sludge
Organisms										
Mayflies (Ephemeroptera)	26									
Caddis Flies (Trichoptera)	19									
Midge Flies (Tendipedidae)	440									
Other Diptera (one species)	51									
Roundworms (Nematoda)	19									
Plenaria (Turbellaria)	32									
Fingernail Clams (Pelecypoda)	223									
Snails (Gastropoda)	19								15	
Leeches (Hirudinea)				15		80	158		49	89
Sludgeworms (Oligochaeta)	204	1,652	369		516	5,472	78,121	22,523	20	2,175
Total Kinds	9	1	1	1	1	2	2	1	3	2
Total Per Sq. Meter	1,033	1,652	369	15	516	5,552	78,279	22,523	84	2,264

instructions that the top of sludge was to be considered the bottom of channel.

The 1962 and 1975 cross sections were superimposed and aligned for best fit to determine the amount of scouring and/or deposition. The area of overlap was then calculated. Since each of the 11 areas surveyed had between 3 and 7 individual cross sections, any given cross section is assumed to be the cross section for an incremental length defined as half the distance between the adjoining upstream and downstream cross sections. This length was multiplied by the area to obtain the volume of sludge, either scoured (-) or deposited (+). These data are presented in Table 5.

Since the exact locations of the 1962 cross sections were not known, the comparison of the 1962 and 1975 data can only provide an approximation of the change over the 13 year period. However, the data show that there has been a net increase in sludge deposits during the period. Although these cross sections are not entirely representative of the Mahoning River overall in that they were frequently immediately upstream of dams, a net increase in deposits on the order of 11,400 cu.yds. in the 10 zones covered is indicated. This is equivalent to about 3,100 cu.yds. per mile.

Under natural conditions, a stream will seek a condition of equilibrium where sedimentation will equal scouring. This equilibrium is primarily dependent upon the load received by the stream and the velocity.

The Michael J. Kirwan Dam and Reservoir was constructed in 1966. This reservoir resulted in a new hydraulic regime which further reduced flood flows and thus reduced the removal of sediment by scouring. During the period 1962-1975, no major flood event of the magnitude of the 1959 flood occurred, and it is likely that no complete scouring took place during the period. Sufficient data, however, do not exist on the sediment loading of the Mahoning between 1962 and 1975 or the period prior to 1962 to compare loading variations.

In summary, it appears that there has been a net increase in sludge deposits during the period 1962-1975, and the river may not yet have reached a condition of sediment equilibrium.

F. SLUDGE DEPOSITS

In order to compute the present total volume of sludge, the data obtained by the Pittsburgh District during the April 1975 river study

TABLE 5

CHANGE IN SLUDGE VOLUME BETWEEN 1962 AND 1975

Zone	Approximate River Mile	Length of Zone in Miles	Change in Volume yds^3/zone
0	3.8	0.255	+1000
1	11.1	0.415	-1800
2	13.1	0.245	+3500
3	18.3	0.150	-2000
4	21.2	0.275	+4200
5	22.2	0.330	+1000
6	23.2	0.255	+6900
7	27.1	0.490	+4400
8	32.0	0.505	-4100
9	34.2	0.450	-1500
10	40.0	0.310	- 200

Net change in volume, cu.yds. = +11,400

was compared to information on base maps of the river prepared in 1965 for the Lake Erie-Ohio River Canal study.

The sediment deposit in the river had been tabulated by a uniform sampling method, which consisted of the following steps:

1. Since the sediment was usually found no more than about twenty feet from shore, the depth of the sludge at this point was determined by poling. If no sludge was found, it was recorded that zero sludge existed along the bank of the river at this location. If a deposit was found, the amount was recorded.

2. To determine the extent of the sediment, other checks for sludge were made at ten foot increments farther from the shore, until no sludge was found.

3. The reported findings were then tabulated giving the sludge depth found twenty feet from shore, and the measured depth found at the most distant ten foot increment from shore. The portion of the river over which this condition was found to exist was indicated on the river maps, along with the depths at the distances from the shore.

The computed volume of sludges were based on the following assumptions:

1. Where no sludge was found twenty feet from shore, no sludge at all existed at that location.

2. Where a depth of sludge was found only at the location twenty feet from shore, the sludge was assumed to exist at a uniform depth over a width of twenty feet.

3. Where sludge was found at a distance more than twenty feet from shore, the first twenty foot increment was calculated as in item (2) and the depth for the second increment was assumed to be the average of the depths stated at twenty feet and at the farthest point from shore.

4. Where sludge was found in the middle of a channel, a uniform depth existed shoreward to the next measured depth.

The river was divided into 12 reaches for purposes of computing volumes of sludges. A reach is defined as the river section between two adjacent low head dams. The low head dams and reaches are shown in Figure 2.

Volumes were then computed for the various reaches of the river between the dams. For Reach number 9, which was inaccessible by boat to measure the sludge depths, it was assumed that the sludge deposits existed in an amount equal to the average rate of deposition of the two reaches on either side of this portion of the river. The tabulated volumes are shown in Table 6 for the twelve reaches. It should be noted that no volume is indicated in Reaches 1 and 2 which lie upstream of the remains of a small dam near Burbank Park in Warren, Ohio. Although the study ended about one-half mile upstream of this dam, only a small deposit was apparent in Reach 2, and it was considered too small to be included in the tabulation for this report.

To indicate the spatial relationship of the sludge with respect to river miles, a graph of cumulative sludge deposits for each reach versus river mile is shown in Figure 10. Beginning with zero at the downstream face of the dam at the upper end of the reach, sludges were added extending to the upstream face of the dam at the lower end of the reach.

It should be noted that the reaches are of different lengths so that all other things being equal, a longer stream reach would show a higher cumulative sludge deposit than the shorter reach, even though both reaches may have the same concentration of sludge in terms of sludge volume/river mile. Besides showing the magnitude of sludge deposits in each reach, the drawing also indicates the concentration of deposits within each reach by the steepness of the curve between any two points. A horizontal portion of the curve would show that no sludge deposits were found in that section of the river.

Figure 10 also shows a "Pollutant Index" based on U.S. EPA criteria for polluted sludges and the analyses of the Mahoning River sludge. Public Law 91-611 directs the Corps of Engineers to dispose of harbor dredgings in confined disposal facilities as opposed to open lake dumping when sediments are deemed polluted by U.S. EPA.

EPA has established the following criteria for determining whether or not sediments are polluted:

	Oil and Grease	COD	Volatile Solids	Total Kjeldahl Nitrogen	Zinc	Lead	Mercury
% dry weight	0.15	5.0	6.0	0.10	0.005	0.0005	0.0001

TABLE 6

SLUDGE DEPOSITS

Reach	Length of Reach in Miles	Quantity in Cubic Yards	Cubic Yds. per River Mile
1	0.9	-	
2	2.7	-	
3	2.6	8,700	3,300
4	3.2	5,000	1,600
5	9.8	213,800	21,800
6	3.8	11,800	3,100
7	2.1	9,000	4,300
8	2.9	7,600	2,600
9	1.9	7,600*	4,000*
10	3.3	17,500	5,300
11	6.1	3,400	600
12	6.9	3,400	500
Total	42.6	287,800	
Average			6,800

*Estimate based on average of adjacent reaches.

FIGURE-10

CUMULATIVE SLUDGE DEPOSITS FOR EACH REACH and POLLUTANT INDEX

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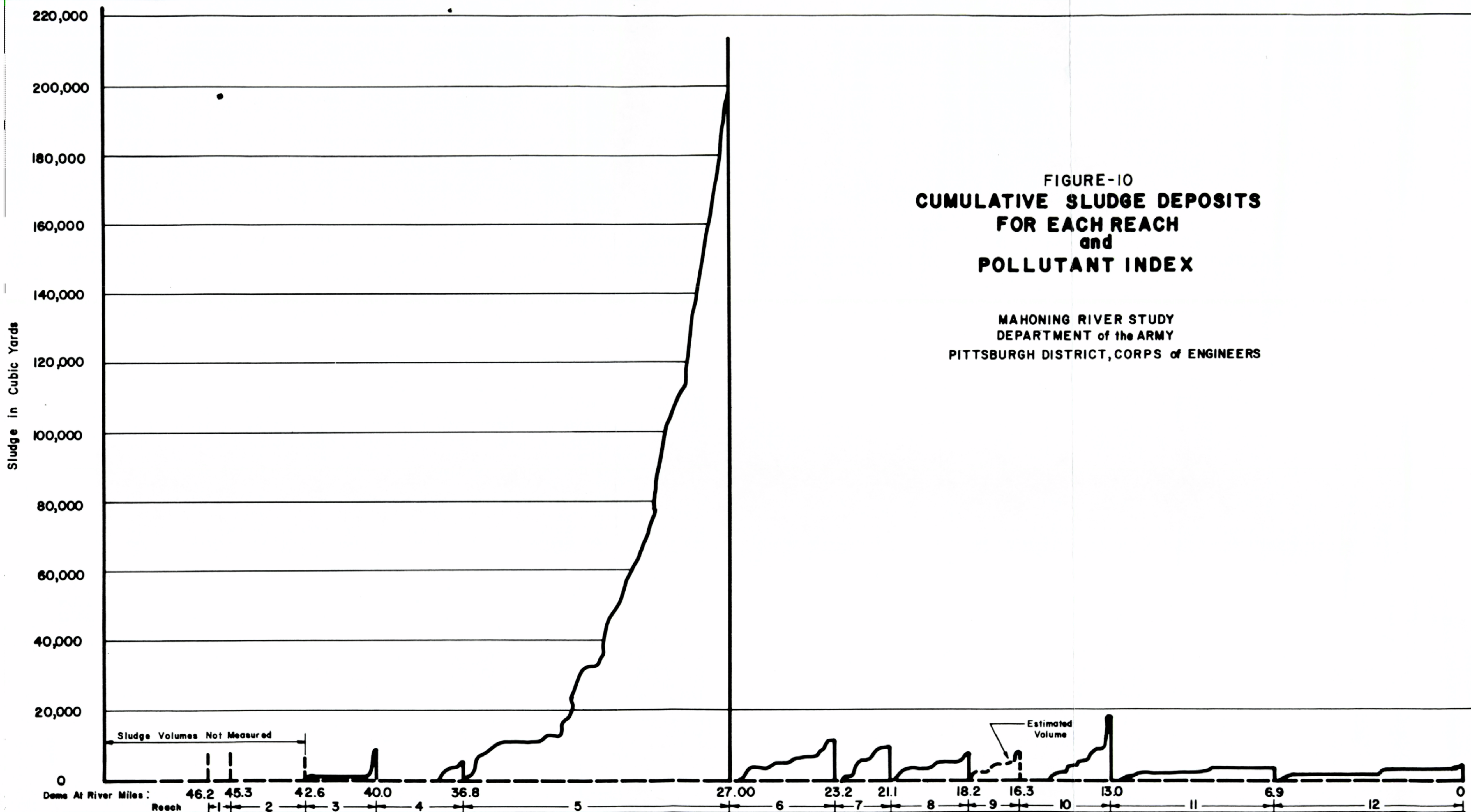

Pollutant Index		46.2	40.1	33.8	30.7	27.1	24.0	22.9
at River Mile		46.2	40.1	33.8	30.7	27.1	24.0	22.9
Source of Data		EPA	H&E	EPA	EPA	H&E	EPA	EPA
PARAMETER	Average	0.2	5.6	2.7	10.8	12.2	6.9	6.4
	Oil & Grease	0.01	4.8	0.5	0.9	1.8	11.3	17.0
	COD	0.1	3.1	0.2	5.2	5.5	2.4	3.0
	VS	0.1	1.3	0.3	2.6	1.7	1.3	1.2
	TKN	0.1	1.8	0.2	2.9	2.6	2.2	0.9
	Zinc	0.7	11.6	13.0	39.8	50.8	20.0	10.6
	Lead	0.3	11.0	2.2	13.4	11.0	4.0	5.8

Pollutant Index		18.0	16.0	13.8	12.9	7.0	1.8
at River Mile		18.0	16.0	13.8	12.9	7.0	1.8
Source of Data		EPA	EPA	H& E	EPA	EPA	EPA
PARAMETER	Average	8.5	10.2	17.7	18.0	13.1	16.6
	Oil & Grease	14.7	16.0	24.5	10.0	18.0	21.3
	COD	2.8	3.6	6.7	3.4	3.4	3.6
	VS	1.0	2.0	2.4	1.8	1.7	1.4
	TKN	1.4	2.3	4.5	2.3	1.9	1.8
	Zinc	25.8	24.8	53.4	73.0	43.2	58.0
	Lead	5.6	12.8	4.7	17.4	10.4	13.8

NOTE: A VALUE EQUAL TO OR GREATER THAN 1.0 CONSTITUTES POLLUTED SEDIMENTS AS DEFINED BY EPA.

If the analysis of sediments shows one or more of the above constituents to exceed the EPA criteria, the sediments are determined to be polluted.

The "Pollutant Index" was developed by determining the percent of each constituent on a dry weight basis and dividing this percentage by the EPA determined percentage for polluted sediments. A number equal to or greater than 1 for any one of the constituents would characterize the sediment as polluted. To provide an indication of the overall quality of the sediments at each sampling station, the indices for each constituent were averaged. Therefore, an Average Pollutant Index of 5.6 as was found at River Mile 40.1, would indicate that the sediments are 5.6 times the level deemed polluted by U.S. EPA. It should be emphasized, however, that any one constituent exceeding 1.0 will characterize the sediment as polluted. Although mercury is one of the constituents in the EPA criteria for determining polluted sediments, it has not been presented here due to the wide range of values obtained.

G. OIL-SOAKED BANKS

In addition to the sludge deposits within the river channel, extensive oil-soaked banks are found along the Mahoning River. This condition was found to exist in an appreciable amount in Reaches 5 through 10 (Republic Steel dam in Warren at River Mile 36.8 to the Lowellville dam at River Mile 13.0). In the District's April 1975 study, the amount and penetration of oil in the banks was noted and this information was shown on the same river maps mentioned in the previous section.

The banks were observed by canoeing the river in three sections on three different days. The flows measured at the USGS gaging stations nearest to the section observed on a given day have been recorded. The following table presents these data:

		Flow (cfs) At:		
River Section Observed	Date	Leavittsburg Gage River Mile 46.1 Avg.Ann.Flow-590	Youngstown Gage River Mile 23.0 Avg.Ann.Flow-860	Lowellville Gage River Mile 12.9 Avg.Ann.Flow-1,086
RM 46.2-27.0	10/27/75	550		
RM 27.0-13.0	10/28/75		749	
RM 13.0-0.0	11/5/75			666

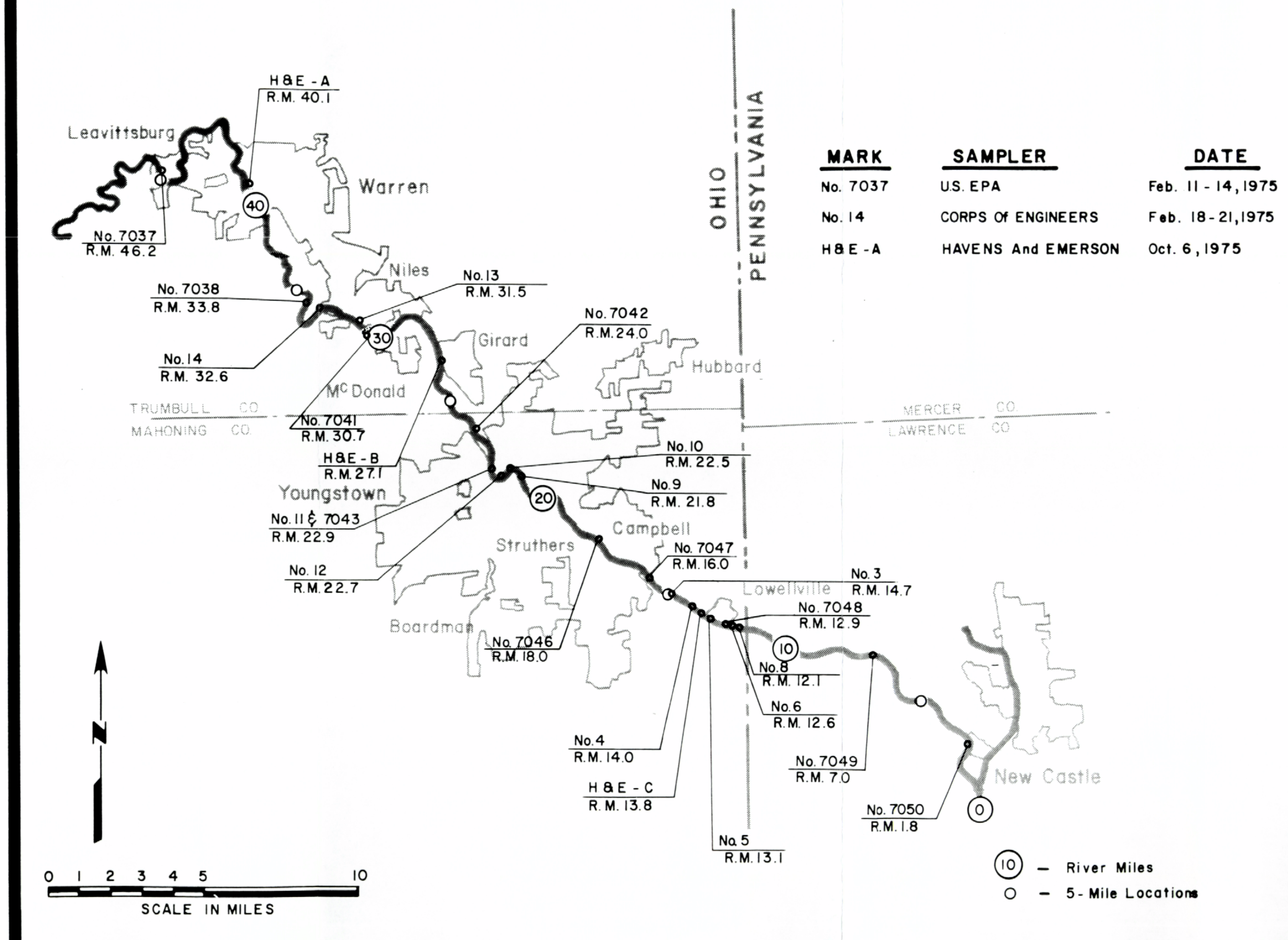

FIGURE - 11
SEDIMENT SAMPLING STATIONS

MAHONING RIVER STUDY
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As indicated in this table, oil-soaked banks were observed when river flows were close to or less than the annual averages and therefore reflect the average to slightly more than average expanse of oil-soaked bank material. Oil-soaked banks were observed extending from the water's edge to the high water mark on the bank and extending beneath the water surface to a distance of up to 15 feet. The physical characteristics of the banks vary from being mildly sloping to very steeply sloped, almost perpendicular, where stream modification has been made principally adjacent to industrial development. In the mildly sloping sections, the oily material extends from the water's edge up the bank for a distance of approximately 30 feet. In the steeply sloped stretches, the extent of the oil-soaked banks is significantly reduced.

The depth of the oil-soaked material on the banks above the water's edge rarely exceeded 6 inches, while the depth at the water's edge was most often approximately four feet. The depth of the oily material diminished rapidly extending away from the bank, although there were some areas where the oil-soaked bank material above the water's edge was several feet deep. Observation of the river banks indicated that they eventually become unstable as the oil saturates the soil. Sloughing of the banks is evident and displaced material tends to fall into the river at the water-land interface. To estimate the volume of oil-soaked banks, an average amount was assumed to exist uniformly throughout Reaches 5 through 10. The oil-soaked banks were estimated to be twenty feet wide and eighteen inches deep for each bank, yielding approximately twelve thousand cubic yards per River Mile for a total of 285,600 cubic yards for the 23.8 miles so affected.

H. SEDIMENT CHARACTERISTICS

Detailed sediment collections and analyses have been performed by both the District and the U.S. Environmental Protection Agency. In the course of this study, three additional samples were collected by Havens and Emerson for additional analysis. The location of each of these sediment collection points is shown in Figure 11.

Sediment analyses, as water quality determinations, represent transient conditions and the integrated impact of upstream point and nonpoint pollution sources. Stream flows have an obvious impact upon the extent of bank formation and sediment deposit and their inherent quality characteristics. Stream flow characteristics, as reported at each gage, during each sediment sampling run are given below:

Sampling Organization	Leavittsburg Range	Leavittsburg Avg.	Youngstown Range	Youngstown Avg.	Lowellville Range	Lowellville Avg.
U.S. EPA, cfs (cfs/SM)	830-860	840 (1.46)	1040-1080	1060 (1.18)	1250-1300	1280 (1.19)
Corps of Engineers, cfs (cfs/SM)	1610-2330	2080 (3.60)	2630-4410	3750 (4.17)	2840-4430	3890 (3.62)
Havens and Emerson, cfs (cfs/SM)		990 (1.72)		1830 (2.03)		1720 (1.60)

Average stream flows during each sampling run were greater than the annual average which exhibits an approximate runoff coefficient of 1.0 cfs/SM. Stream flows during the Corps' sampling run were in excess of the maximum monthly value observed during the five years of record encompassing the 1968 through 1973 time frame. The approximate percent of the time that average flows will exceed the values found during the sediment sampling runs is as follows:

U.S. EPA - 35 to 45 percent of the time
Corps of Engineers - Less than 1.5 percent of the time
Havens and Emerson - 15 to 30 percent of the time

Table 7 summarizes the sediment analyses for each reporting organization. A wide variability in results is seen. A wide variation is observed between the mercury levels reported by the Corps (Samples 3 through 14) and the U.S. EPA (Samples 7037 through 7050), with the Corps' values consistently greater than 1.0 mg/kg and the U.S. EPA values consistently less than 1.0 mg/kg. Havens and Emerson's mercury measurements appear to more closely agree with the values reported by the U.S. EPA. It is believed that these mercury differences reflect sampling procedure differences rather than changing sediment characteristics. At the time the Corps of Engineers were limiting their sampling to the very worst areas to get an indication of the severity of pollution. Iron concentrations in the bottom sediments are most striking, ranging from a low of less than one percent at River Mile 46.2 to over 40 percent at River Mile 22.9. Most typically, however, iron levels in the bottom deposits range from 10 to 20 percent of the dry solids mass. Oil and grease values also vary widely with a low at River Mile 46.2 (0.01 percent) to a high at River Mile 22.7 (12 percent).

Examination of the Pollutant Index in Figure 10 shows that only the sediment collected at River Mile 46.2 would classify as nonpolluted. Samples collected above the Liberty Street Dam (Reach 5), above the Lowellville Dam (Reach 10), and downstream of the Lowellville Dam to the

TABLE 7

SEDIMENT ANALYSES
(Sheet 1/5)

Sample ID. River Mile	7037 46.2	A 40.1	7038 33.8	14 32.6	13 31.5
Total Solids %	72.6	37.7	80.0	21.8	30.8
S.G. @ 25°C	-	1.45	-	1.17	1.25
pH units	-	7.0	-	8.0	7.6
Fecal Coliform No/100 ml	-	-	-	0	400
Volatile Solids mg/kg*	8,300	77,500	12,600	-	-
COD mg/kg	5,300	153,000	7,500	-	-
Oil and Grease mg/kg	<10	7,140	800	52,700	49,100
TKN mg/kg	100	1,800	160	-	-
NH_3-N (1) mg/l	15	12	68	51	47
Total PO_4-P mg/kg	280	2,290	680	-	-
Fluorides mg/kg	-	-	-	335	250
Phenols mg/kg	0.4	0.27	0.75	0.96	<0.3
Total CN mg/kg	0.06	1.46	1.4	85	131
Free CN mg/kg	-	-	-	<5	<3
Aluminum mg/kg	3,560	12,900	8,440	-	-
Arsenic mg/kg	3	0.6	19	72	30
Barium mg/kg	-	104	-	362	320
Cadmium mg/kg	<1	2.0	2	<5	<3
Chromium mg/kg	15	1,220	68	770	740
Copper mg/kg	6	460	210	-	-
Iron mg/kg	7,800	228,000	330,000	-	-
Lead mg/kg	15	549	110	1,000	650
Manganese mg/kg	155	3,060	1,640	-	-
Mercury mg/kg	<0.1	0.2	<0.1	36	3
Nickel mg/kg	50	1,140	180	-	-
Selenium mg/kg	-	-	-	<230	<160
Silver mg/kg	-	4.6	-	73	73
Zinc mg/kg	36	580	650	-	-

*All mg/kg on dry weight basis.
(1) Soluble phase.

TABLE 7 (CONT'D.)

SEDIMENT ANALYSES
(Sheet 2/5)

Sample ID.	7041	B	7042	7043	11
River Mile	30.7	27.1	24.0	22.9	22.9
Total Solids %	31.3	30.5	50.3	34.0	23.4
S.G. @ 25°C	-	1.27	-	-	1.19
pH Units	-	7.5	-	-	7.7
Fecal Coliform No/100 ml	-	-	-	-	1,300
Volatile Solids mg/kg*	156,000	104,000	63,100	69,700	-
COD mg/kg	260,000	276,000	120,000	150,000	-
Oil and Grease mg/kg	1,300	2,760	17,000	17,000	31,000
TKN mg/kg	2,900	2,630	2,200	870	-
NH_3-N (1) mg/l	73	29	110	36	36
Total PO_4-P mg/kg	2,200	3,220	2,400	1,200	-
Fluorides mg/kg	-	-	-	-	360
Phenols mg/kg	3.8	0.28	0.6	1.8	1.7
Total CN mg/kg	4.8	1.24	4.2	8.8	49
Free CN mg/kg	-	-	-	-	<4
Aluminum mg/kg	295	16,600	14,900	18,900	-
Arsenic mg/kg	13	1.1	12	26	65
Barium mg/kg	-	180	-	-	166
Cadmium mg/kg	4	3.7	2	3	<4
Chromium mg/kg	370	472	310	23	624
Copper mg/kg	330	331	170	115	-
Iron mg/kg	200,000	269,000	83,000	410,000	-
Lead mg/kg	670	548	200	290	420
Manganese mg/kg	3,220	2,310	2,330	4,160	-
Mercury mg/kg	0.2	0.8	0.2	0.1	20
Nickel mg/kg	360	300	150	50	-
Selenium mg/kg	-	-	-	-	<210
Silver mg/kg	-	4.2	-	-	34
Zinc mg/kg	1,990	2,540	1,000	530	-

*All mg/kg on dry weight basis.
(1) Soluble phase.

TABLE 7 (CONT'D.)

SEDIMENT ANALYSES
(Sheet 3/5)

Sample ID.	12	10	9	7046	7047
River Mile	22.7	22.5	21.8	18.0	16.0
Total Solids %	39.5	34.1	27.8	47.1	50.0
S.G. @ 25°C	1.31	1.30	1.25	-	-
pH Units	7.9	7.8	7.7	-	-
Fecal Coliform No/100 ml	1,800	1,000	600	-	-
Volatile Solids mg/kg*	-	-	-	56,900	117,000
COD mg/kg	-	-	-	140,000	180,000
Oil and Grease mg/kg	120,000	32,100	24,030	22,000	24,000
TKN mg/kg	-	-	-	1,400	2,300
NH_3-N (1) mg/l	128	23	10	44	68
Total PO_4-P mg/kg	-	-	-	2,800	2,400
Fluorides mg/kg	265	208	377	-	-
Phenols mg/kg	4.6	1.3	<0.4	1.3	4.2
Total CN mg/kg	29	75	56	25	6.4
Free CN mg/kg	<3	<3	<4	-	-
Aluminum mg/kg	-	-	-	8,300	17,000
Arsenic mg/kg	67	72	30	2	14
Barium mg/kg	250	117	<4	-	-
Cadmium mg/kg	13	18	36	1	4
Chromium mg/kg	471	395	490	150	220
Copper mg/kg	-	-	-	145	190
Iron mg/kg	-	-	-	155,000	190,000
Lead mg/kg	815	580	503	280	640
Manganese mg/kg	-	-	-	1,690	1,970
Mercury mg/kg	25	16	16	0.1	0.2
Nickel mg/kg	-	-	-	155	190
Selenium mg/kg	<130	<150	<180	-	-
Silver mg/kg	50	35	252	-	-
Zinc mg/kg	-	-	-	1,290	1,240

*All mg/kg on dry weight basis.
(1) Soluble phase.

TABLE 7 (CONT'D.)

SEDIMENT ANALYSES
(Sheet 4/5)

Sample ID. River Mile	3 14.7	4 14.0	C 13.8	5 13.1	7048 12.9
Total Solids %	49.2	52.5	33.8	49.6	42.7
S.G. @ 25°C	1.47	1.51	1.25	1.44	-
pH Units	7.6	8.0	7.2	8.1	-
Fecal Coliform No/100 ml	1,300	2,000	-	1,800	-
Volatile Solids mg/kg*	-	-	144,000	-	107,000
COD mg/kg	-	-	335,000	-	170,000
Oil and Grease mg/kg	34,400	30,000	36,700	49,300	15,000
TKN mg/kg	-	-	4,520	-	2,300
NH_3-N (1) mg/l	59	152	140	21	22
Total PO_4-P mg/kg	-	-	4,080	-	1,400
Fluorides mg/kg	317	270	-	327	-
Phenols mg/kg	0.8	1.0	0.4	0.7	0.9
Total CN mg/kg	52	34	1.4	65	14
Free CN mg/kg	<2	<2	-	<2	-
Aluminum mg/kg	-	-	17,200	-	19,100
Arsenic mg/kg	14	42	0.2	31	9
Barium mg/kg	<2	95	234	202	-
Cadmium mg/kg	<2	<2	3.0	<2	4
Chromium mg/kg	300	530	314	431	260
Copper mg/kg	-	-	179	-	320
Iron mg/kg	-	-	142,000	-	190,000
Lead mg/kg	500	476	734	645	870
Manganese mg/kg	-	-	1,650	-	2,210
Mercury mg/kg	31	20	1.1	24	0.5
Nickel mg/kg	-	-	216	-	270
Selenium mg/kg	<100	<100	-	<100	-
Silver mg/kg	100	76	2.1	24	-
Zinc mg/kg	-	-	2,670	-	3,650

*All mg/kg on dry weight basis.
(1) Soluble phase.

TABLE 7 (CONT'D.)

SEDIMENT ANALYSES
(Sheet 5/5)

Sample ID. River Mile	6 12.6	8 12.1	7049 7.0	7050 1.8
Total Solids %	27.6	34.9	44.1	44.0
S.G. @ 25°C	1.22	1.28	-	-
pH Units	7.4	7.4	-	-
Fecal Coliform No/100 ml	4,200	0	-	-
Volatile Solids mg/kg*	-	-	104,000	84,500
COD mg/kg	-	-	170,000	180,000
Oil and Grease mg/kg	23,800	46,000	27,000	32,000
TKN mg/kg	-	-	1,900	1,800
NH_3-N (1) mg/l	30	37	65	78
Total PO_4-P mg/kg	-	-	3,500	3,500
Fluorides mg/kg	195	261	-	-
Phenols mg/kg	0.4	<0.3	1.8	2.5
Total CN mg/kg	84	44	15	17
Free CN mg/kg	<4	<3	-	-
Aluminum mg/kg	-	-	17,200	23,100
Arsenic mg/kg	59	51	27	14
Barium mg/kg	282	115	-	-
Cadmium mg/kg	<4	23	5	6
Chromium mg/kg	438	402	110	150
Copper mg/kg	-	-	165	255
Iron mg/kg	-	-	147,000	230,000
Lead mg/kg	706	747	520	690
Manganese mg/kg	-	-	1,690	2,150
Mercury mg/kg	22	26	0.4	0.5
Nickel mg/kg	-	-	150	200
Selenium mg/kg	<180	<140	-	-
Silver mg/kg	71	69	-	-
Zinc mg/kg	-	-	2,160	2,900

*All mg/kg on dry weight basis.
(1) Soluble phase.

Shenango confluence (Reaches 11 and 12), appear most polluted. Zinc levels in the bottom deposits contribute most heavily to each sample's overall pollutional rating. The zinc content in all of the samples below River Mile 46.0 is at least ten times greater than the standard limit. The oil and grease content of the bottom sediments is the second most significant pollutant characteristic, with the standard exceeded by ten or more times from River Mile 24.0 downstream. The probable source of the polluted sediments is poorly defined due to intermixing, resuspension, and downstream deposition.

In an effort to define significant differences between top, bottom and bank sediment characteristics, as well as the existing and ultimate solubility of the pollutants within the sediments, additional samples were collected and analyses performed. The results of these special samples are contained in Tables 8 and 9.

Table 8 defines the top, bottom and bank deposit characteristics for a stream section at River Mile 13.8. The analyses (carbon, hydrogen, oxygen, sulfur, nitrogen, and energy content expressed in BTU's/lb.) at the bottom of the Table reflect the ultimate analysis of a dry sediment sample. Significant differences between the top and bottom pollutant characterization are only observed with the arsenic and nickel values with the bottom sediments containing appreciably higher percentages of these two pollutants. A comparison of the bottom sediments against the bank deposits show that the bank deposits contain a much lower fraction of oxidizable components such as BOD, COD, oil and grease, nitrogen, cyanide, and sulfide. Iron, and perhaps manganese, are higher in the bank deposits, which may reflect the higher oxidative state. All other measured components of the bank deposits exhibit similar percentage characteristics. Initially, solubility characteristics of each pollutant are concentration and environmentally dependent. Only the soluble mercury levels exhibited a noticeable dependency upon the location of the sludge sample, with the highest soluble level found in the top sediment sample and the lowest soluble level found in the bank deposit. Of most significance, in terms of initial availability, is the percent soluble cyanide which ranged from 16 to 25 percent of the total cyanide mass.

Table 9 compares the initial and citrate solubility of the pollutants as a function of polluted state of the deposits using samples collected at River Miles 40.1, 27.1, and 13.8. Citrate solubility tests are conventionally utilized in soils and fertilizer analysis to determine the true availability of nutrients. Such a test simulates the weak organic acid environment created by soil micro-organisms, and can be utilized to approximate the ultimate availability of a given pollutant.

TABLE 8

DEPOSIT CHARACTERISTICS AT RIVER MILE 13.8

	River Sediment				Bank	
	Top		Bottom(1)		-	
	Total	Soluble*	Total	Soluble*	Total	Soluble*
TS - kg/l	0.426	0.28	0.342	0.30	0.721	0.16
S.G. @ 25°C	1.25		1.22		1.42	
VTS - mg/kg	144,000	0.78	137,000	1.06	98,700	1.07
BOD_5 - mg/kg	14,000	0.25	15,800	0.12	7,490	0.16
BOD_{21} - mg/kg	56,800	0.53	84,200	0.99	25,800	0.73
COD - mg/kg	335,000	0.15	364,000	0.14	244,000	0.15
Oil and Grease - mg/kg	36,700	0.08	42,200	0.06	19,900	0.06
TKN - mg/kg	4,520	8.1	3,360	7.6	2,680	2.2
NH_3-N - mg/l	140	100	76	100	32	100
PO_4-P - mg/kg	4,310	0.08	4,800	0.04	4,230	0.015
Phenol - mg/kg	0.40	<14.7	0.44	<16.7	0.48	<7.4
CN_{total} - mg/kg	1.41	16.7	1.17	25.0	0.61	22.7
Aluminum - mg/kg	17,200	0.006	16,400	<0.008	14,500	0.006
Arsenic - mg/kg	0.2	7.0	7.0	0.21	0.1	19
Barium - mg/kg	234	0.32	234	0.25	196	0.25
Cadmium - mg/kg	3.0	0.16	4.4	<0.39	3.1	<0.27
Chromium - mg/kg	314	<0.005	392	0.015	302	<0.009
Copper - mg/kg	179	0.005	223	0.012	207	0.014
Iron - mg/kg	142,000	0.029	164,000	0.004	206,000	0.001
Lead - mg/kg	734	0.010	620	0.042	723	0.008
Manganese - mg/kg	1,650	0.087	1,780	0.043	1,990	1.95
Mercury - mg/kg	1.1	6.2	0.9	0.88	0.9	0.16
Nickel - mg/kg	216	0.022	111	0.011	161	0.043
Silver - mg/kg	2.1	<1.1	3.9	<1.9	2.4	<1.4
Zinc - mg/kg	2,670	0.005	3,000	0.005	2,540	0.004
Sulfide - mg/kg	718	0.006	1,110	0.0	304	0.0
$TOC_{soluble}$ - mg/kg	260	100	200	100	220	100
Carbon - mg/kg	146,500		143,700		113,200	
Hydrogen - mg/kg	13,700		13,700		10,300	
Oxygen - mg/kg	40,500		37,200		21,700	
Sulfur - mg/kg	4,400		4,500		3,200	
Nitrogen - mg/kg	2,800		3,000		2,500	
BTU - BTU/lb	2,320		2,385		1,680	

*Defined as percent of total pollutant mass.

(1) Possible sample disturbance during collection.

TABLE 9

IMMEDIATE AND ULTIMATE POLLUTANT SOLUBILITY

River Mile	Top of Stream Deposit 40.1			Top of Stream Deposit 27.1			Top of Stream Deposit 13.8		
	Total	Soluble*	Citrate Soluble*	Total	Soluble*	Citrate Soluble*	Total	Soluble*	Citrate Soluble*
TS - kg/l	0.547	0.11	-	0.387	0.19	-	0.426	0.28	-
VTS - mg/kg	77,500	0.11	-	104,000	0.25	-	144,000	0.78	-
BOD_5 - mg/kg	14,100	0.067	-	14,300	0.051	-	14,000	0.25	-
BOD_{21} - mg/kg	51,200	0.19	-	63,500	0.46	-	56,800	0.53	-
COD - mg/kg	153,000	0.12	-	276,000	0.13	-	335,000	0.15	-
Oil and Grease - mg/kg	7,140	0.15	<0.36	2,760	2.2	6.1	36,700	0.08	9.7
TKN - mg/kg	1,800	1.9	-	2,630	3.4	-	4,520	8.1	-
NH_3-N - mg/l	12	100	-	29	100	-	140	100	-
PO_4P - mg/kg	2,290	0.044	92	3,230	0.039	89	4,310	0.077	78
Phenol - mg/kg	0.27	73.3	-	0.28	<22.7	-	0.40	<14.7	-
CN_{total} - mg/kg	1.46	<8.8	-	1.24	<10.4	-	1.41	16.7	-
Aluminum - mg/kg	12,900	0.012	1.2	16,600	0.016	1.8	17,200	0.006	0.72
Arsenic - mg/kg	0.58	1.2	100	1.1	1.1	100	0.2	7.0	100
Barium - mg/kg	104	0.61	74	180	0.47	89	234	0.32	72
Cadmium - mg/kg	2.0	<0.18	11	3.7	<0.14	21	3.0	<0.16	25
Chromium - mg/kg	1,220	<0.001	1.2	472	<0.005	3.3	314	<0.005	3.1
Copper - mg/kg	457	0.002	0.26	331	0.004	0.17	179	0.005	0.45
Iron - mg/kg	228,000	0.013	2.4	269,000	0.008	2.5	142,000	0.029	1.4
Lead - mg/kg	549	0.007	0.70	548	0.005	0.63	734	0.010	0.50
Manganese - mg/kg	3,060	0.16	52	2,310	0.064	44	1,650	0.087	52
Mercury - mg/kg	0.24	2.3	<0.5	0.82	0.62	<0.16	1.1	6.2	0.24
Nickel - mg/kg	1,140	0.008	24	300	0.021	28	216	0.022	17
Silver - mg/kg	4.6	<0.40	<8.3	4.2	<0.60	16	2.1	<1.14	19
Zinc - mg/kg	580	0.041	22	2,540	0.015	3.4	2,670	0.005	3.6
Sulfide - mg/kg	110	1.35	-	537	0.0336	-	718	0.006	-
$TOC_{soluble}$ - mg/l	160	100	-	42	100	-	260	100	-
Carbon - mg/kg	54,900			102,100			146,500		
Hydrogen - mg/kg	8,900			10,800			13,700		
Oxygen - mg/kg	10,200			25,100			40,500		
Sulfur - mg/kg	2,100			4,200			4,400		
Nitrogen - mg/kg	1,700			2,000			2,800		
BTU - BTU/lb	930			1,590			2,320		

*Defined as percent of total pollutant mass.

Standard procedures were utilized to make up the ammonium citrate solution which was adjusted to a neutral pH.* Thereafter, using a dry solids to citrate solution ratio of 4 gms per 100 ml, the samples were given 24 hours of contact, with vigorous mixing for the first eight hours. The final analyses were performed on the filtrate from a Whatman No. 1 Filter Pad; the same filtering media was utilized for the initial solubility tests.

The data summarized in Table 9 indicate that the ultimate solubility of the measured pollutant is usually several orders of magnitude greater than the initial solubility. Phosphorus, arsenic and barium exhibit the highest solubilities, with a range of 72 to 100 percent of the original mass. The ultimate solubility of the bound manganese appears to be approximately 50 percent. Cadmium, nickel, and possibly silver, demonstrate an ultimate solubility somewhat greater than 10 percent and probably less than 30 percent. The ultimate solubility of the oil and grease, aluminum, chromium, iron and zinc appears to be in the range of 1 to 10 percent soluble, with the zinc showing a definite solubility dependency upon the initial zinc mass present. Copper and lead solubilities are typically observed in the 0.1 to 1.0 percent range. The mercury results are not conclusive with the initial solubility measurements being consistently higher than the ultimate solubility values and higher than the total at River Mile 40.1 and 13.8. The reason for these observations are not known. Although pesticides and PCB's were not analyzed as part of this study, they would be determined by the standard elutriate test prior to initiation of any dredging activity.

I. SEDIMENT-WATER QUALITY INTERRELATIONSHIPS

1. Low Flow Analysis

Critical low flow from the standpoint of water quality normally coincides with the highest ambient temperatures and the lowest stream flows. The most critical low flow is one that shows the highest biochemical reaction rates (temperature dependent) with the lowest time of travel (stream flow dependent). Natural streams in Ohio can be expected to experience this maxima during the July through October period. This situation may not be true for the Mahoning, however, due to the extensive thermal load introduced to the River, the number of pools behind the River's low head dams, and the regulated stream flows.

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*"Official Methods of Analysis", Association of Official Analytical Chemists, 12th Edition, 13, 2.036 (1975).
Jackson, Mil., "Soil Chemical Analyses", Prentice Hall, Inc., Englewood Cliffs, New Jersey (1960).

Maximum allowable temperatures for the Mahoning River in Ohio have been defined by the Ohio Environmental Protection Agency. Thus, the values cited in Table A-1 Sheet 5/5 become a constant. Similarly, the Ohio EPA has also established a critical summer and winter low flow condition which has been defined in Table 3 and is also accepted as a governing value. The remaining variable and the most difficult to define is the stream time of travel for these particular flow conditions. The only available information concerning this variable is a July 1975 dye study conducted by the USGS and other cooperating agencies. The results of this study, made available by the Ohio EPA, are summarized in Table 10. Stream flows during this investigation ranged from slightly greater than the OEPA summer minimum to the approximate annual average.

The information provided in Table 10, the information gathered during the April, 1975 cross-sectioning of the River, and the published profile of the River from the Flood Plain Information Studies, could be utilized in computer programs to establish the time of travel for any flow regime with subsequent validation by the dye study. Although computer modeling was not utilized in this study, a number of equations and relationships can be used to determine velocity characteristics.

One technique is to examine the velocity relationships observed at the USGS Gaging Stations. These relationships can be developed from USGS Standard Form 207 data and the equations of hydraulic continuity. The relationships and their correlation coefficients are shown in Table 11. In such a data treatment, the multiple of the coefficients and the sum of the exponents should approach unity. The correlation coefficients for the velocity relationships are seen to be the worst for each station. The velocity equations at Leavittsburg and Lowellville reflect the normal flow dependency with velocities increasing with flows. The velocity equation at the Youngstown Gage, which had the poorest correlation coefficient of the three, shows the highly unusual condition of a declining velocity with a higher flow. This is obviously due to a significant change in stream width with only a minimal change in stream depth. Such an observation may be due to the backwater impact of Mill Creek or merely reflective of the curve fitting technique between the data points. In reality it is probable that the velocity in any stream stretch could be determined by a similar equation with the exponent somewhere between the minimums observed at Leavittsburg and Lowellville and unity. Unity would correspond to a hypothetical condition where pool backwater volumes do not expand with increasing flows. Backplotting the dam crest elevations from the Lowellville Gage to Market Street in Warren, reveals only two natural gradient sections. The first encompasses about 0.75 miles below Youngstown Sheet and Tube in the 3.3 mile stream section in Reach 10. The second is a 0.8 mile stretch immediately

TABLE 10

SUMMARY OF DYE STUDIES ON MAHONING RIVER
(22, 24 and 25 July, 1975)

Segment	River* Mile	Distance (miles)	Flow (cfs)	Dye Peak Travel Time (Hours)	Average Velocity (fps)
Market Street, Warren	39.0				
		7.6	410	12	0.93
Main Street, Niles	31.4				
		4.4	540	13	0.50
Liberty Street, Girard	27.0				
		4.1	560	9.9	0.61
Bridge Street, near Youngstown Gage	22.9				
		4.4	580	8.0	0.81
Center Street, Youngstown	18.5				
		5.6	1,025	6.2	1.32
Lowellville Bridge, near Gage	12.9				
		5.9	1,100	4.9	1.76
Edinburg Road, (SR 224, Pa.)	7.0				
		5.3	1,170	5.1	1.52
Newcastle (SR 108, Pa.)	1.7				

*River Mile stationing of this report.

TABLE 11

HYDRAULIC CONTINUITY EQUATIONS AT USGS GAGING STATIONS
(USGS Standard Form 207 Data)

Equation	Leavittsburg	Youngstown	Lowellville
Velocity = C_1Q^{n1} (fps)	$0.17Q^{0.40}$	$4.4Q^{-0.14}$	$0.04Q^{0.56}$
Correlation Coefficient	0.66	0.36	0.87
Width = C_2Q^{n2} (ft)	$57Q^{0.11}$	$34Q^{0.22}$	$91Q^{0.10}$
Correlation Coefficient	0.92	0.96	0.93
Depth = C_3Q^{n3} (ft)	$0.09Q^{0.52}$	$0.007Q^{0.91}$	$0.33Q^{0.31}$
Correlation Coefficient	0.92	0.86	0.98
$(C_1)(C_2)(C_3)$	0.87	1.05	1.20
$n_1+n_2+n_3$	1.03	0.99	0.97

Q=cfs

below Market Street in Warren. Since the true exponent is not known, it was decided to use a worst case analysis for the low flow condition and assign an exponent of unity to the pooled stretches. Undoubtedly, the true velocity for the low flow condition would be somewhat greater than that predicted. Thus, under critical low flow conditions, the impact of the sediments would be somewhat less than predicted.

Table 12 provides the information utilized to define the critical low flow condition for stream segments. In the interest of completeness, a new segment above Market Street was added with assumed flows, velocities and time of travel for the previously cited dye study. Stream velocities for the critical winter (win.) and summer (sum.) flow releases were assumed directly proportional to flow changes. This assumption results in a worst case statement for the calculated time of travel. The maximum allowable temperatures are those stated by the Ohio Environmental Protection Agency and, in Pennsylvania, the criteria for warm water fisheries. The 15.6°C winter temperature for segment 8 is the maximum allowable March temperature. The temperature factor, 1.05^{T-20}, is the standard adjustment factor for biological activity. The final two columns in the Table can be used to compare the summer and winter critical low flow condition for each stream segment.

As shown, for the worst case assumptions of this analysis, the critical biochemical rate factor occurs during the winter for the stream segments encompassing River Miles 31.4 to 7.0. Above and below this stretch of the River, the critical low flow condition occurs in the summer.

The stream widths and falls can be approximated using the data collected during the April 1975 detailed cross-sectioning of the River. These dimensions are given in Table 13 for the eight segments. Also shown on this table (normalized to 20°C by use of the equation 1.05^{T-20}) are the measured average benthic oxygen demand rates reported by the U.S. EPA for the given stream reaches.[1] The reported background level is defined as the benthic oxygen uptake rate measured at Leavittsburg. In the absence of urban point and nonpoint discharges, the benthic oxygen demand in the lower 46 miles of the river would approach that measured at Leavittsburg.

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(1) Personal communication from A.R. Winklohofer, Director, Michigan-Ohio District Office, U.S. EPA (October, 1975).

TABLE 12

CRITICAL LOW FLOW DEFINITION

Segment	Segment Definition (River Mile) From	To	Length (miles)
1	Leavittsburg Dam (46.2)	Market Street (39.0)	7.2
2	Market Street (39.0)	Main Street (31.4)	7.6
3	Main Street (31.4)	Liberty Street (27.0)	4.4
4	Liberty Street (27.0)	Bridge Street (22.9)	4.1
5	Bridge Street (22.9)	Center Street (18.5)	4.4
6	Center Street (18.5)	Lowellville Bridge (12.9)	5.6
7	Lowellville Bridge (12.9)	Edinburg Road (7.0)	5.9
8	Edinburg Road (7.0)	Newcastle (1.7)	5.3

Segment	Time of Travel Definition: Flow (cfs) Dye	Flow Win	Flow Sum	Velocity (fps) Dye	Velocity Win	Velocity Sum	Travel Time (Hrs.) Dye	Travel Time Win	Travel Time Sum
1	390*	145	315	1.1*	0.41	0.89	9.6	25.7	11.9
2	410	170	340	0.93	0.38	0.77	12.0	29.4	14.5
3	540	230	455	0.50	0.21	0.42	13.0	31.0	15.5
4	560	237	464	0.61	0.25	0.49	9.9	24.2	12.3
5	580	320	540	0.81	0.45	0.75	8.0	13.4	8.1
6	1,025	330	550	1.32	0.42	0.71	6.2	19.5	11.5
7	1,100	340	560	1.76	0.54	0.90	4.9	16.0	9.6
8	1,170	360	600	1.52	0.47	0.78	5.1	16.5	9.9

Segment	Temperature Relationships: Max. Allow (°C)(1) Winter	Max. Allow Summer	Factor = 1.05^{T-20} Winter	Factor Summer	Bio-Chemical Rate Factor(2) (Hrs.) Winter	Bio-Chemical Rate Factor(2) (Hrs.) Summer
1	4.4	25.8	0.47	1.33	12.1	15.8
2	14.4	30.0	0.76	1.63	22.3	23.6
3	20.0	33.9	1.00	1.97	31.0	30.5
4	20.0	33.9	1.00	1.97	24.2	24.2
5	33.9	35.0	1.97	2.08	26.4	16.8
6	33.9	35.0	1.97	2.08	38.4	23.9
7	28.3	33.3	1.50	1.91	24.0	18.3
8	15.6	32.2	0.81	1.81	13.4	17.9

* Assumed

(1) As defined by Ohio and Pennsylvania water quality standards.
(2) Temperature adjusted travel time
= (Travel time, hours)(Temperature Factor, Unitless)

TABLE 13

PHYSICAL CHARACTERISTICS AND OXYGEN UPTAKE RATES OF STREAM SEGMENTS

					Benthic Total Oxygen Demand at 20°C			O_2 Demand at T_{max} (Lbs/Day)			
								"As Is"		Background	
Segment	River Miles	Ave. Width (Ft)	Area (SF)	Fall (Ft)	Measured mg/SF Day	"As Is" Lbs/Day	Background Lbs/Day	Win	Sum	Win	Sum
1	46.2-39.0	160	$6.1x10^6$	23	220	2,950	2,410	1,390	3,200	1,140	2,610
2	39.0-31.4	100	$4.0x10^6$	16	150	1,320	1,580	1,000	3,510	1,200	4,200
3	31.4-27.0	180	$4.2x10^6$	0.2	260	2,400	1,660	2,400	4,730	1,660	3,270
4	27.0-22.9	160	$3.5x10^6$	7	300	2,310	1,390	2,310	4,550	1,390	2,740
5	22.9-18.5	150	$3.5x10^6$	17	380	2,160	1,390	4,260	4,490	2,740	2,890
6	18.5-12.9	170	$5.0x10^6$	22	550	6,050	1,980	11,920	12,580	3,900	4,120
7	12.9-7.0	160	$5.0x10^6$	20	240	2,640	1,980	3,960	5,040	1,300	1,650
8	7.0-1.7	140	$3.9x10^6$	15	110	940	1,540	760	1,700	1,240	2,780

* Background defined as the benthic demand of sediments measured at Leavittsburg.
Background Benthic Oxygen Demand = 180 mg/SF Day.

The data in Table 13 can be utilized to calculate the approximate oxygen transfer due to reaeration through the technique proposed by Tsivoglou and Wallace[2], where

$$\text{Oxygen Transfer} = D_o\ (1-e^{-K_2 t}), \text{ and } K_2 = \frac{C\Delta h}{t}$$

where
D_o = initial oxygen deficit
K_2 = reaeration coefficient
C = escape coefficient
Δh = fall distance, feet, in stream segment
t = time of travel

If it is assumed that the minimum allowable stream dissolved oxygen concentration is 5 mg/l, the maximum allowable deficit can be set for each stream segment as a function of the previously reported temperature limits (Table A-1 Sheet 5/5). If the escape coefficient is set at 0.05 for 20°C, in presumption that the Mahoning point wastewater sources are controlled to a level that avoids extremely polluted conditions, then the mg/l of oxygen reaeration in a given stream stretch can be calculated as shown in Table 14.

The data in Tables 13 and 14 can then be used to approximate the impact of the sediments in the absence of point and nonpoint pollutant additions, as shown in Table 15. These data, which are portrayed graphically on Figure 12, confirm the initial low flow analysis reported at the beginning of this chapter, namely, that the critical low flow condition is found in the winter with a predicted violation of the 5 mg/l dissolved oxygen standard derived from combination of low stream flows, elevated temperatures, and polluted sediments accumulated between the dams at mile points 13 and 16.3. The major reason for this violation is the allowance of maximum stream temperatures of 33.9°C in the reach between Yellow Creek (River Mile 15.8) and Mill Creek (River Mile 22.2) and 28.3°C in the reach between Yellow Creek and Lowellville. The predicted result for the summer months confirms the results of the U.S. EPA, where a water quality model showed the presence or absence of

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(2) Tsivoglou, E.C., and Wallace, J.R., Characterization of Stream Reaeration Capacity, EPA-R3-72-012, Office of Research and Monitoring, U.S. Environmental Protection Agency, Washington, D.C. 20460.

TABLE 14

OXYGEN SUPPLIED BY REAERATION

Segment	Max. T(°C)		D_o (mg/l)		CΔh	Temp Adj. 1.02^{T-20}		Reaeration O_2 Supply (mg/l)	
	Win	Sum	Win	Sum	-	Win	Sum	Winter	Summer
1	4.4	25.8	8.0	3.2	1.15	0.73	1.12	4.6	2.3
2	14.4	30.0	5.3	2.6	0.80	0.89	1.22	2.7	1.6
3	20.0	33.9	4.2	2.2	0.01	1.0	1.32	0.0	0.0
4	20.0	33.9	4.2	2.2	0.35	1.0	1.32	1.3	0.8
5	33.9	35.0	2.2	2.1	0.85	1.32	1.35	1.5	1.4
6	33.9	35.0	2.2	2.1	1.10	1.32	1.35	1.7	1.6
7	28.3	33.3	2.9	2.3	1.00	1.18	1.30	2.0	1.7
8	15.6	32.2	5.1	2.4	0.75	0.92	1.27	2.6	1.5

Reaeration O_2 Supply = $D_o\ [1-e^{-C\Delta H(1.02)^{T-20}}]$

TABLE 15

OXYGEN BUDGET CALCULATIONS

Segment	Travel Time (Hrs)	Sediment O_2 Demand (mg/1)* "As Is"	Sediment O_2 Demand (mg/1)* Background	Reaeration O_2 Added (mg/1)	Net O_2 Gain (mg/1) "As Is"	Net O_2 Gain (mg/1) BKGD	Segment DO (mg/1) In "As Is"	Segment DO (mg/1) In BKGD	Segment DO (mg/1) Out "As Is"	Segment DO (mg/1) Out BKGD	Final DO Controlled By "As Is" BKGD
WINTER											
1	25.7	1.9	1.6	4.6	0	0	13.0	13.0	13.0	13.0	Temperature
2	29.4	1.3	1.6	2.7	-2.7	-2.7	13.0	13.0	10.3	10.3	Temperature
3	31.0	2.5	1.7	0.0	-2.5	-1.7	10.3	10.3	7.8	8.6	Sediments
4	24.2	1.8	1.1	1.3	-0.5	+0.2	7.8	8.6	7.3	8.8	Sediments
5	13.4	1.4	0.9	1.5	-0.1	-1.6	7.3	8.8	7.2	7.2	Temperature
6	19.5	5.4	1.8	1.7	-3.7	-0.1	7.2	7.2	3.5	7.1	Sediments
7	16.0	1.4	1.0	2.0	+0.6	+1.0	3.5	7.1	4.1	8.1	Sediments
8	16.5	0.3	0.5	2.6	+2.3	+2.1	4.1	8.1	6.4	10.2	Sediments
SUMMER											
1	11.9	0.9	0.7	2.3	0	0	8.2	8.2	8.2	8.2	Temperature
2	14.5	1.2	1.4	1.6	-0.6	-0.6	8.2	8.2	7.6	7.6	Temperature
3	15.5	1.2	0.8	0.0	-1.2	-0.8	7.6	7.6	6.4	6.8	Sediments
4	12.3	0.9	0.5	0.8	-0.1	+0.3	6.4	6.8	6.3	7.1	Sediments
5	8.1	0.5	0.3	1.4	+0.8	0.0	6.3	7.1	7.1	7.1	Temperature
6	11.5	2.0	0.6	1.6	-0.4	0.0	7.1	7.1	6.7	7.1	Sed. Temp.
7	9.6	0.7	0.5	1.7	+0.4	+0.2	6.7	7.1	7.3	7.3	Temperature
8	9.9	0.2	0.3	1.5	+0.1	+0.1	7.3	7.3	7.4	7.4	Temperature

*mg/1 Sediment O_2 Demand = $\left(\frac{\text{Travel Time, Hrs.}}{24}\right)(O_2 \text{ Demand, Lbs/Day})\left(\frac{1}{\text{Flow in reach, cfs}}\right)\left(\frac{1}{5.39}\right)$

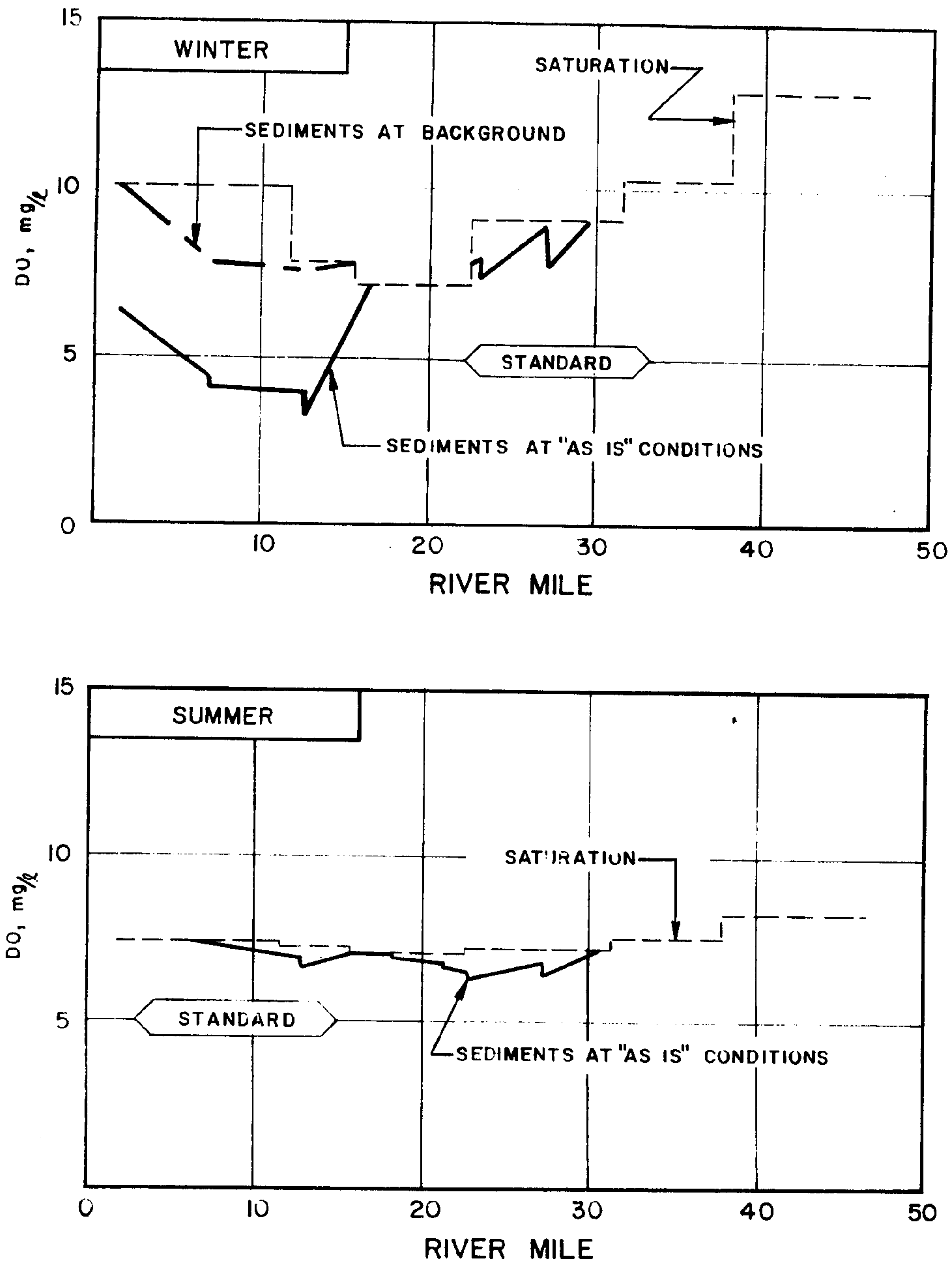

FIGURE - 12

CRITICAL LOW FLOW DISSOLVED OXYGEN PROFILES

MAHONING RIVER STUDY
DEPARTMENT OF THE ARMY
PITTSBURGH DISTRICT, CORPS OF ENGINEERS

sediments had no more impact than about 0.5 mg/l.* The Ohio Environmental Protection Agency is currently addressing the apparently more critical winter period.

The reader should remember that the conclusion concerning the impact of the sediments was derived with a worst case analysis and that the technique utilized probably understates the true velocity (and travel time) in any stream reach. Further, it should be remembered that the analysis assumes that maximum temperatures are met and maintained throughout the stream reach, that reaction rates follow the indicated temperature dependency throughout the entire range of concern and that the same benthic oxygen demands are applied across the entire stream area. Finally, it should also be noted that the occurrence of the OEPA minimum winter flows is extremely unlikely since this period normally corresponds to elevated natural stream flows. On the other hand, this analysis has excluded the impact from all pollutant sources except those associated with the sediments. Other point and non-point oxygen demanding pollutants may serve to depress the stream dissolved oxygen to the level predicted for the winter condition.

Table 16 examines the impact of the sediments in terms of the existing and proposed future point source controls. Again, the assumption is made that the present sediments can be cleaned up only to the point that their oxygen uptake rate approaches that measured at Leavittsburg. This Table also shows the total mass of oxygen demanding pollutants released to each reach and the amount stabilized in each reach per the decay coefficient cited by the U.S. EPA (0.3 $days^{-1}$, base e at 20°C) with a temperature adjustment factor of 1.05^{T-20}*. Source control releases are those defined by the Ohio EPA.

The results show that under present "as is" conditions, the sediments contribute approximately 21 to 29 percent of the total oxygen demand satisfied in the Mahoning River with the assumption that dissolved oxygen levels are not depressed below 5.0 mg/l. If point source pollutant abatement programs are implemented and the sediment quality is

*Personal Communication from G. Amendola, Chief, Ohio Support Branch, Michigan - Ohio District Office, U.S. EPA (December 1975).

*Personal Communication from A.R. Winklohofer, Director, Michigan-Ohio District Office, U.S. EPA (October 1975).

TABLE 16

TOTAL OXYGEN DEMAND PER SEGMENT

Segment	Sediment C_2 Demand 1000 Lbs				Waste Releases 1000 Lbs of BOD_{20}				BOD_{20}Stabilized 1000 Lbs*				Sediment % of C_2 Demand			
	As Is		Background		As Is		Source Control		As Is		Source Control		As Is		Source Control	
	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum
1	1.5	1.9	1.2	1.6	3.1	1.7	0.9	0.5	0.4	0.7	0.1	0.2	79	73	92	89
2	1.2	2.1	1.5	2.5	21.2 (23.9)	10.4 (11.4)	5.4 (6.2)	2.6 (2.9)	4.8 (5.4)	5.1 (5.6)	1.2 (1.4)	1.3 (1.4)	20 (18)	29 (27)	55 (52)	65 (64)
3	3.1	3.1	2.1	2.1	30.3 (48.8)	15.2 (21.0)	3.6 (8.4)	1.8 (3.1)	9.0 (14.4)	7.4 (10.2)	1.1 (2.6)	0.9 (1.6)	26 (18)	30 (23)	66 (45)	70 (57)
4	2.3	2.3	1.4	1.4	10.4 (44.8)	5.3 (16.1)	1.7 (7.5)	0.8 (2.3)	3.1 (13.2)	3.1 (9.4)	0.5 (2.2)	0.5 (1.4)	42 (15)	42 (20)	74 (39)	74 (50)
5	2.4	1.5	1.5	1.0	11.6 (43.2)	7.0 (13.7)	4.6 (9.9)	2.8 (3.7)	6.9 (25.7)	4.4 (8.6)	2.7 (5.8)	1.7 (2.2)	26 (9)	25 (15)	36 (21)	37 (31)
6	9.7	6.0	3.2	2.0	16.1 (33.6)	9.5 (14.6)	3.4 (7.5)	2.0 (3.5)	9.5 (19.8)	5.9 (9.1)	2.0 (4.4)	1.2 (2.1)	51 (33)	50 (40)	62 (42)	62 (49)
7	2.6	2.0	0.9	0.6	0.2 (14.0)	0.1 (5.6)	0.1 (3.2)	0.1 (1.5)	0.1 (6.3)	0.1 (3.2)	0.1 (1.4)	0.1 (0.9)	96 (29)	95 (38)	90 (39)	86 (40)
8	0.5	0.7	0.8	1.1	0 (7.7)	0 (2.4)	0 (1.8)	0 (0.6)	0 (1.9)	0 (1.3)	0 (0.4)	0 (0.3)	100 (26)	100 (35)	100 (67)	100 (79)
Total	23.3	19.6	12.6	12.3	92.9	49.2	19.7	10.6	33.8 (87.1)	26.7 (48.1)	7.7 (18.3)	5.9 (10.1)	41 (21)	42 (29)	62 (41)	68 (55)

*(BOD_{20} Stabilized) = BOD_{20}release[1-e$^{-0.3\text{(temp. adjust)(travel time, days)}}$]

(   ) = Actual Values applied to or stabilized in stream segments.

the same as measured at Leavittsburg ("background and quality"), then the sediments amount to approximately 41 to 55 percent of the total oxygen demand satisfied in the Mahoning River. The Table predicts that with a point source control program that reduces the release of oxygen demanding pollutants by 79 percent, the oxygen demanding impact of the bottom sediments can be reduced by no more than 46 percent. The lack of any appreciable reaeration in segment 3 and the elevated temperature in segments 5 and 6 make these stream stretches the most stressed from the standpoint of oxygen resource considerations.

If it is assumed under the low flow regime that the only pollutants available for release are those in the soluble phase, the data collected by Havens and Emerson (Table 8, Table 9) show that only iron, mercury, nickel, oil and grease, phenol, silver, and zinc, are at soluble levels in the sediments that exceed the Ohio Warm Water Fisheries Water Quality Standards. In order to examine the impact of these pollutants, it was assumed that the release rate was equal to that found for the benthic oxygen demand. It was then assumed that once a pollutant is released, it remains soluble and, where applicable, no degradation occurs. Table 17 was created with these assumptions. The final in-stream concentration is calculated using the cumulative total of the upstream releases. This data work-up shows that the iron standard may be violated in segments 1, 2, 5, 7, and 8, due to sediment pollutant releases. In practice, such a condition is unlikely due to instream oxidation and reprecipitation of the iron. Soluble silver concentrations may also approach or exceed the 0.001 mg/l standard in the same segments. As with the oxygen demanding pollutants, with the exception of segment 1, the maximum impact of these pollutants is also exerted during the critical low flow of the winter period.

2. High Flow Analysis

The high flow analysis of the watershed can be approached from two standpoints. The first incorporates the turbidity data reported in Section C. These data can be used to quantify the water quality characteristics resulting from sediment resuspension. The second examines the amount of sediments and bank material that may be resuspended and scoured from the stream as a function of the flow condition. These data can be utilized to establish a perspective on the effectiveness of control procedures and the natural restorative powers of the river from the context of sediment water quality interrelationships.

a. Turbidity Data Analysis

Figure 7 of Section C indicates that once flows at the Lowellville Gage slightly exceed the OEPA summer minimum or reach about 600 cfs,

TABLE 17

CRITICAL LOW FLOW POLLUTANT CONCENTRATIONS
DUE TO SEDIMENT RELEASES

Segment	Pollutant Release Rate mg/SF Day mg/l soluble		Sediment Pollutant Concentration mg/l soluble	Soluble Pollutant Releases from Sediments						Pollutant Level in Stream* mg/l		Ohio Water Quality Standard mg/l
				mg/SF Day		mg/Day (10^6)		mg (10^6)				
	Win	Sum		Win	Sum	Win	Sum	Win	Sum	Win	Sum	
1 and 2	3.7	8.0										
Iron			16	59	128	600	1,300	1,400	1,400	1.6	1.6	1.0
Mercury			0.003	0.011	0.024	0.11	0.24	0.25	0.26	0.0003	0.0003	0.0005
Oil and Grease			6	22	48	220	480	510	530	0.57	0.59	5.0
Phenol			0.11	0.41	0.88	4.1	8.8	9.4	9.7	0.011	0.011	0.1
Silver			<0.01	0.037	0.08	0.37	0.80	0.85	0.88	0.0010	0.0010	0.001
Zinc			0.13	0.48	1.04	4.8	10.8	11	12	0.012	0.013	0.075-0.5
3, 4 and 5	4.5	4.8										
Iron			8	36	38	400	430	1,100	640	0.95	0.77	1.0
Mercury			0.002	0.009	0.010	0.10	0.11	0.28	0.16	0.0002	0.002	0.0005
Oil and Grease			24	108	115	1,200	1,300	3,400	1,900	1.5	0.92	5.0
Phenol			<0.025	0.11	0.12	1.2	1.3	3.4	1.9	0.005	0.004	0.1
Silver			<0.01	0.045	0.048	0.50	0.54	1.4	0.81	0.0008	0.0006	0.001
Zinc			0.15	0.68	0.72	7.6	8.1	22	12	0.012	0.009	0.075-0.5
5, 7 and 8	7.3	7.7										
Iron			18	131	139	1,800	1,900	3,900	2,500	1.7	1.2	1.0
Mercury			0.003	0.022	0.023	0.30	0.32	0.65	0.41	0.0003	0.0002	0.0005
Oil and Grease			12	88	92	1,200	1,300	2,600	1,700	1.7	1.1	5.0
Phenol			<0.025	0.18	0.19	2.5	2.6	5.4	3.3	0.005	0.004	0.1
Silver			<0.01	0.073	0.077	1.0	1.1	2.2	1.4	0.0011	0.0008	0.001
Zinc			0.06	0.44	0.46	6.1	6.4	13.2	8.3	0.012	0.008	0.075-0.5

*Based upon cumulative totals.

stream turbidity values never drop below 15 units. The highest measured turbidity value is 50 units. If it is assumed that the suspended solids: turbidity ratio is 2:1 (a value which is realistic for wastewater but, due to a lack of documentation on this river, is somewhat speculative) and that these suspended solids have the same pollutant characteristics as the bottom deposits, then an instream pollutant concentration due to resuspension of the bottom sediments can be calculated as shown in Table 18. This Table, using the characteristics as reported by Havens and Emerson at River Mile 13.8 for the "as is" condition and the characteristics as reported by the U.S. EPA at River Mile 46.2 for the background condition, shows the pollutant characteristics over the range of measured turbidities reported at Leavittsburg. The data indicate that the "as is" sediment characteristics will cause a violation of only three of the 14 listed pollutants in the measured range of turbidities for the assumed conditions. The most stringent copper and zinc standard (corresponding to a hardness concentration less than or equal to 80 mg/l as $CaCO_3$) is violated when the suspended solids exceed 28 mg/l. At 55 mg/l of instream suspended solids associated with resuspended sediments, a violation of the lead water quality standard is predicted. In terms of the other parameters, suspended solids concentrations of 500 mg/l would result in violation of the mercury and silver water quality standards with oil and grease rising above the allowable limit when a suspended solids concentration of 135 mg/l is exceeded. Suspended solids concentrations in excess of 1000 mg/l are not considered likely for any flow regime. Therefore, water quality violations due to sediment resuspension would not be anticipated at this station for phenol, cyanide, arsenic, barium, cadmium, iron, and manganese. It should be noted that the stated violation is based upon a strict interpretation of the water quality standards which, with the exception of iron and manganese, give no credit to the pollutant form (soluble versus particulate). The laboratory data show little immediate solubility and, it can be inferred, little immediate availability to exert any toxic due to upon resuspension. The data also show that if the background characteristics of the sediments could be maintained, then no water quality standard violation would be predicted.

b. Mathematical Analysis of Sediment Transport

Given a slope and a flow with the description of the bed material and sediment load, a stream cross section can be determined which will neither scour nor silt. This cross section can then be compared against measured stream cross sections to determine if deposition or scour would be predicted and the approximate volume of each as a function of selected flow regimes. Alternately, it can be used to establish a stable cross section throughout the course of a River for a narrow flow band. The

TABLE 18

WATER QUALITY DUE TO RESUSPENDED SEDIMENTS

Pollutant	Water Quality Standard	Pollutant Level in Sediment (mg/kg) H & E at R.M. 13.8	USEPA at R.M. 46.2	Pollutant Concentration At SS = 30 mg/1 (1)		SS = 100 mg/1 (2)		Required SS Concentration to Violate Water Quality Standard (mg/1)	
	mg/1	As Is	Background	As Is mg/1	Background mg/1	As Is mg/1	Background mg/1	As Is	Background
Oil and Grease	5.0	36,700	<10	1.1	<0.0003	3.7	<0.0010	135	>500,000
Phenol	0.01	0.4	0.4	0.000012	0.000012	0.000040	0.000040	25,000	25,000
Cyanide	0.20	1.4	0.06	0.000042	0.0000018	0.000140	0.0000060	145,000	3,330,000
Arsenic	0.05	0.2	3	0.000006	0.00009	0.000020	0.00030	250,000	16,700
Barium	0.8	234	-	0.0069	-	0.000300	-	3,500	-
Cadmium	0.005	3	<1	0.000090	<0.00003	0.000300	<0.00010	1,670	>5,000
Chromium	0.30	314	15	0.0093	0.00045	0.031	0.00150	970	20,000
Copper	0.005-0.075	179	6	0.0054	0.00018	0.018	0.00060	28-420	830-12,500
Iron*	1.0	41	-	0.0012	-	0.0041	-	2,450	-
Lead	0.04	734	15	0.022	0.00045	0.073	0.00150	55	2,670
Manganese*	1.0	1.4	-	0.000042	-	0.000140	-	71,500	-
Mercury	0.0005	1.1	<0.1	0.00003	<0.000003	0.00010	<0.000010	500	>5,000
Silver	0.001	2.1	-	0.00006	-	0.00020	-	500	-
Zinc	0.075-0.50	2,670	36	0.081	0.00108	0.270	0.00360	28-185	2,100-13,900

*Soluble basis.
(1) Turbidity = 15 units
(2) Turbidity = 50 units

most common mathematical analysis for this cross section will usually incorporate one of the following techniques:

1) Einstein's Bed-Load Function Method

2) Lacey's Regime Theory

3) Permissive Velocity Method, and

4) Tractive Force Method

Einstein's methodology is considered to be the most realistic of the four techniques. It has been used where extensive analysis of major rivers with a heavy sediment load is considered necessary. The technique, however, is considered far too complex for the limited needs of this study. The other three techniques were largely developed for man-made canals with known uniform cross sections and slopes. Lacey's Regime Theory has found application for the massive irrigation and flow transport projects of the Middle East and has been used with some success in California. It incorporates a variety of coefficients and exponents which are dependent upon the locality of the canal. These "constants" are very difficult to predict without extensive field work over many years. The Permissive Velocity Method is normally used with known uniform cross sections and slopes over a small flow range. It suffers, when applied to a river, in the difficulty of establishing the correct velocity parameter. By process of elimination, then, the Tractive Force Method was selected for use on the Mahoning due to its relative simplicity and greater general applicability. Further detailed discussion of all four techniques and the fundamental theory behind the methodology associated with the Tractive Force Method can be found in standard references.* Appendix B provides a summary of the equations utilized with the Tractive Force Technique with an example solution.

Einstein, H.A. "The Bed-Load Function for Sediment Transportation in Open Channel Flows". U.S. Department of Agriculture, Technical Bulletin No. 1026 (September, 1950).

*Graf, W.H., "Hydraulics of Sediment Transport" McGraw-Hill, N.Y.,N.Y. (1971).
Chow, V.T., "Handbook of Applied Hydrology" McGraw-Hill, N.Y., N.Y. (1964).
Chow, V.T., "Open-Channel Hydraulics" McGraw-Hill, N.Y., N.Y. (1959).

Figure 13 graphically portrays the results of the calculations over the normal range of flows and slopes of the Mahoning for a tractive force (τ_0) of 0.10 lbs/SF. This Tractive Force was selected after a review of the textural descriptions and particle size, size distribution, and shape information obtained for the Mahoning sediments by the Pittsburgh District. As shown in Figure 14, a tractive force of 0.10 lbs/SF seems to give a more reasonable calculated result. Increasing tractive forces are indicative of more stable, large particle stream beds which can tolerate a higher velocity through a cross section.

As mentioned previously, detailed cross sectional information is available from a field study conducted in April 1975 and from a prior study in June 1962. The stream flows during the April 1975 study exceeded the maximum monthly flow measured from October 1968 through September 1973, and June 1962. Stream flows in June 1962 were approximately equal to those between the OEPA winter and summer minimum or 0.43 cfs/SM. Average monthly flows during March 1962 were approximately 4.6 times greater than that associated with the average maximum month. It was presumed that the 1962 information gave a more correct definition of the stream cross section except where the newer data showed an obvious fill or silting situation. Hypothetic cross-sections, as derived from Figure 14 using the slope of the measured stream profile, were imposed upon measured cross-sections to determine the magnitude of the sediments or banks that could be potentially scoured from the River with the average JASO, ANNUAL, FMAM, and maximum month flow regimes. These calculations indicated that in a year's time a total of approximately 600,000 cubic yards of bottom sediments, bank sludges and bank materials can be potentially eroded (and deposited) from River Mile 43 to 11. The total dry weight of this volume was estimated as 830,000 tons with a breakdown of 120,000 tons of bottom sediment, 260,000 tons of bank sludges and 450,000 tons of bank material. Figure 15 shows the mass of river deposits potentially resuspended as a function of river mile and flow regime. The average FMAM (February through May) flow regime is seen to cause the greatest resuspension with the greatest deposit pick-up between River Miles 30 and 20. The mass prediction is, of course, not correct for the River as it now exists due to the presence of the many low head dams. It is probable that true mass potentially resuspended and deposited annually is no more than one-tenth to one-fourth (83,000 to 210,000 tons) of that predicted.

The question of the impact of non-point and point source control on the sediment mass can be addressed with the information provided in the

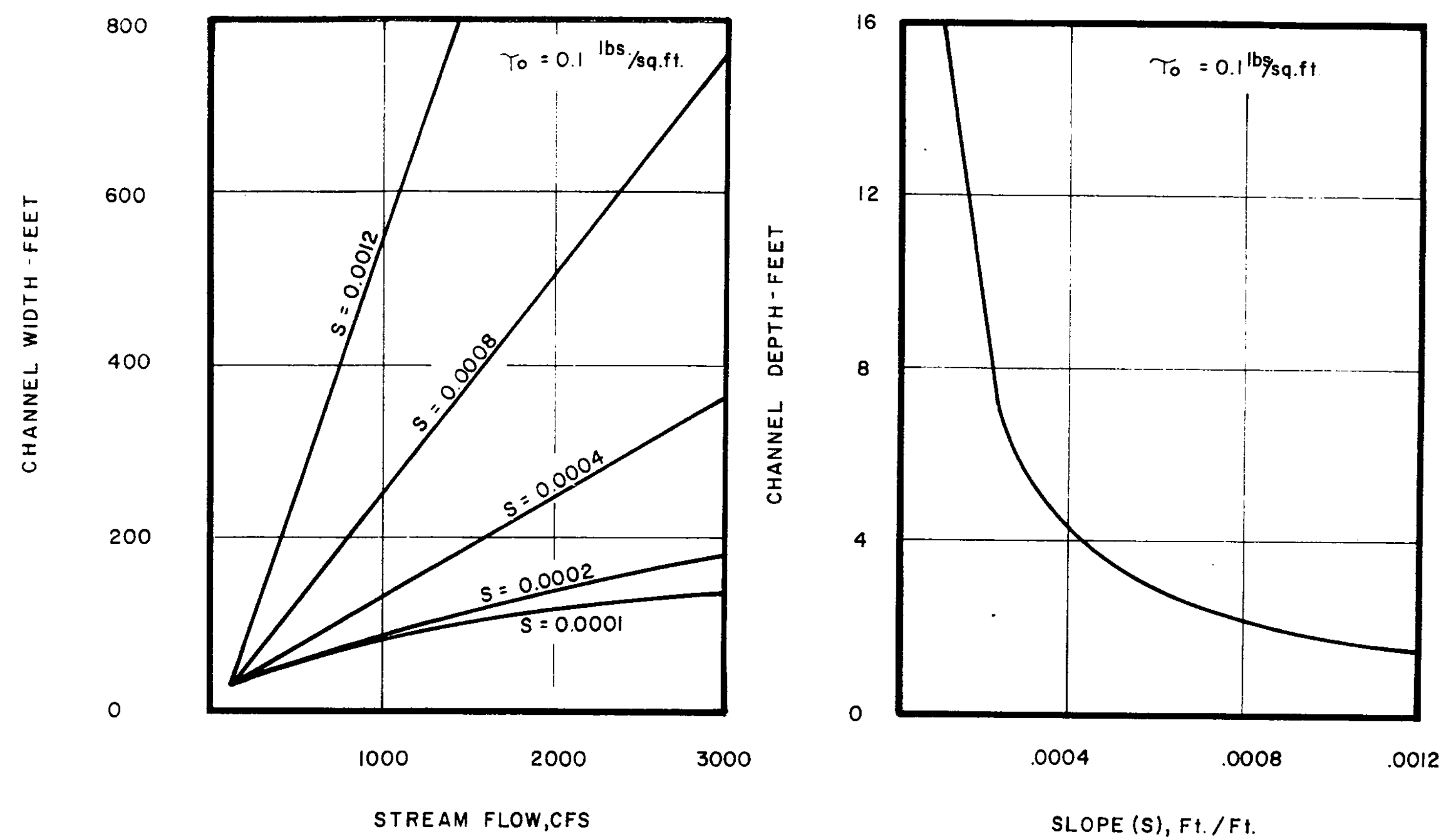

FIGURE - 13

STABLE CROSS SECTION DIMENSIONS

MAHONING RIVER STUDY
DEPARTMENT OF THE ARMY
PITTSBURGH DISTRICT, CORPS OF ENGINEERS

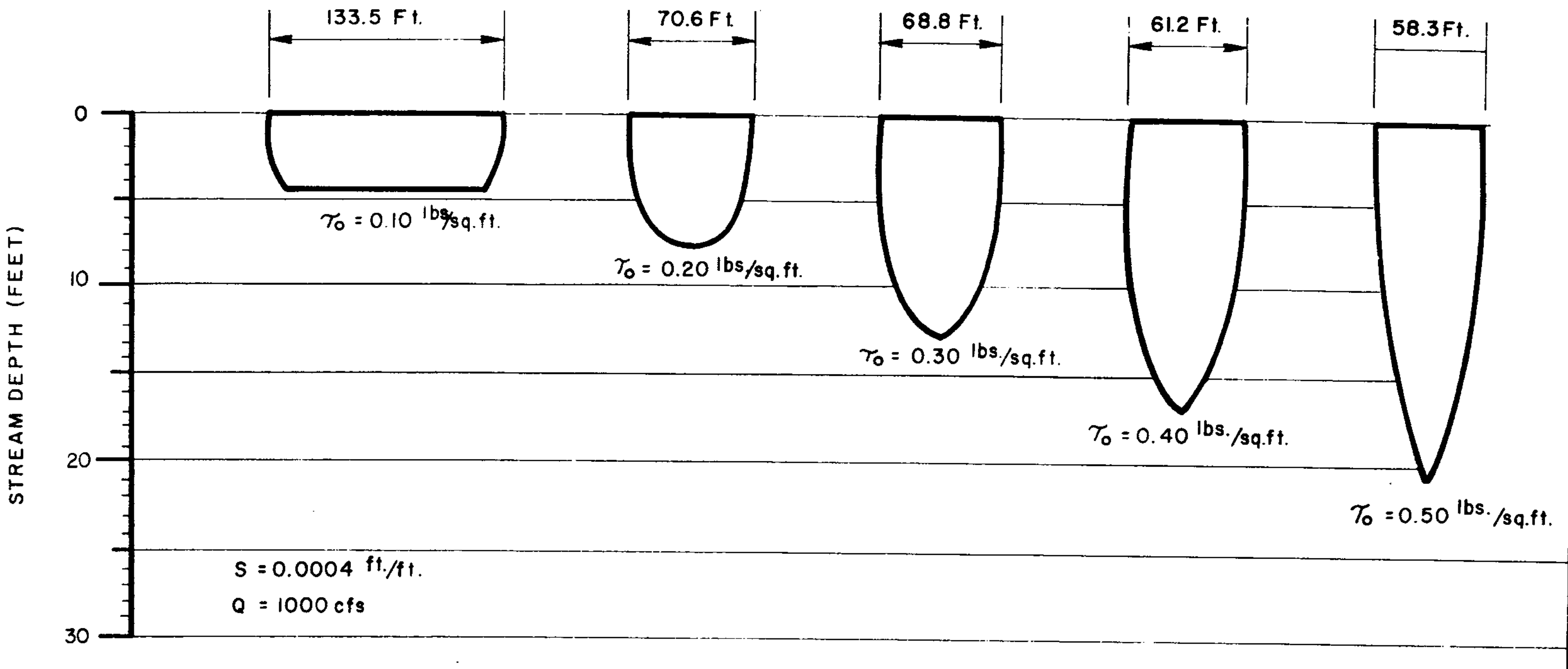

FIGURE - 14

VARIATION OF STABLE CROSS SECTION WITH TRACTIVE FORCE (τ_o)

MAHONING RIVER STUDY
DEPARTMENT OF THE ARMY
PITTSBURGH DISTRICT, CORPS OF ENGINEERS

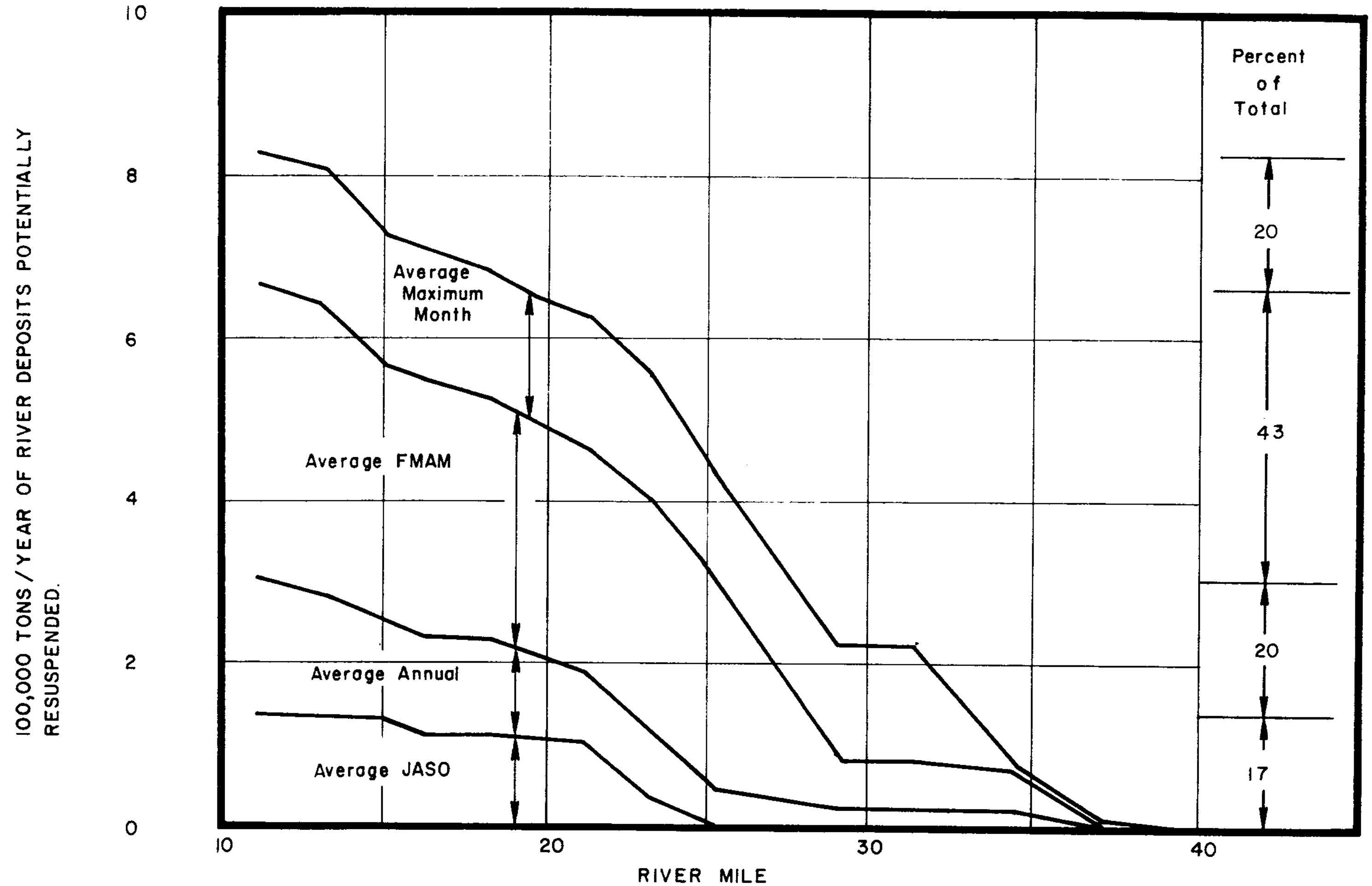

FIGURE - 15
POTENTIAL RESUSPENSION OF RIVER DEPOSITS
VS.
RIVER MILE AND FLOW REGIME

MAHONING RIVER STUDY
DEPARTMENT OF THE ARMY
PITTSBURGH DISTRICT, CORPS OF ENGINEERS

1972 Northeast Ohio Water Plan.* Table 19 shows that the 1970 sediment load actually delivered to the Mahoning was estimated at over 1.2 million tons per year. Of this total, less than 5 percent was associated with urban sediment loads and only 3.2 percent was point source derived while 1.2 percent was non-point. The impact of controlling point sources would therefore have little influence upon the mass of sediment produced in the Mahoning Watershed, even under the most optimistic sediment reduction program. In terms of today's conditions, the measured point release of suspended solids reported during the U.S. EPA's three day survey in February 1975 showed an equivalent annual tonnage of only 19,000 tons. Along the stretch of the Mahoning River from Leavittsburg to the State Line, this same survey showed an annual relerse of nearly 5,500 tons/year of iron, 90 tons/year of cyanide, 94 tons/year of phenol, and 38 tons/year of lead. Currently proposed Ohio EPA Standards anticipate under BPT (Best Practical Treatment for Industry), an annual release of 63 tons/year of cyanide and 17 tons/year of phenol. Heavy metal limits have not been firmly established but they are presumed to be at the same 30 to 82 percent reduction level observed with the cyanide and phenol mass. Thus, if today's source control strategy is implemented on the Mahoning, assuming 90 percent removal of 1970 stream sediment load from point urban sources, it would appear that approximately 20 to 54 percent of the present pollutant load derived from urban sources could be eliminated from the sediments. This would result in a condition that would make restoration of the polluted sediments to a quality condition found in Leavittsburg highly unlikely and essentially unattainable unless the urban combined sewers and storm sewers are also strictly controlled.

Elsewhere in this report, it has been estimated that the potential volume and mass of river deposits that could be dredged from the course of the river is approximately 670,000 cubic yards with a dry weight of 370,000 tons. In this chapter a mass of 83,000 to 210,000 tons has been estimated as being potentially resuspended during a normal year's flow regime. It can be approximated then, that the natural curative powers of the river have the capability of replacing 22 to 57 percent of the anticipated dredgings. Further, if it is presumed the Mahoning's many reservoirs captured approximately fifty to seventy percent of the total sediment load of 1970, as an extreme condition the remaining load would still be sufficient to fill the dredged volume within 10 to 16 months.

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*"Northeast Ohio Water Plan - Plan Formulation and Alternatives". Ohio Department of Natural Resources (November, 1972).

TABLE 19

1970 STREAM SEDIMENT LOAD SUMMARY, TONS/YEAR

(1972 Northeast Ohio Water Plan)

Source	Suspended	Bed	Total	Percent of Total
Farmlands	94,000	375,000	469,000	37.4
Land Development	4,000	9,000	13,000	1.0
Roadside Erosion	1,000	4,000	5,000	0.4
Stream Bank Erosion	213,000	498,000	711,000	56.8
Urban Sediment Loads				
Municipal Wastewater	2,000	3,000	5,000	0.4
Industrial Wastewater	14,000	21,000	35,000	2.8
Combined and Storm Sewers	6,000	9,000	15,000	1.2
TOTAL	334,000	919,000	1,253,000	100.0

Proposed Sediment Reduction Goal

	Percent Reduction of Total Basin Load
Farmlands	17.2
Stream Bank Erosion	14.2
Urban	2.6
TOTAL	34.0

J. SUMMARY AND STATEMENT OF FINDINGS

The previous sections discussed in some detail the quantities of sludges and oil-soaked banks, the quality of these materials, and the impacts these materials have on water quality. The following generalized statements summarize the findings:

1. All the sludges except those upstream of Copperweld (Reaches 1 and 2) violate the U.S. EPA criteria for polluted sediments.

2. The largest single quantity of sludges is located between River Miles 27 to 36.8 (74%).

3. The combined impact of present point and non-point pollutant releases appears to result in the violation of water quality standards at the Pennsylvania-Ohio State Line at almost any flow regime.

4. A worst case analysis with a variety of assumptions was utilized to examine the impact of the sediments, acting alone, upon the oxygen resources of the stream. This analysis revealed the following:

   a. The critical low flow condition for the river stretch studied occurs during the OEPA winter minimum water release, with a violation of the 5 mg/l dissolved oxygen standard predicted in the pool established by the dam at River Mile 13.0.

   b. During the OEPA summer minimum release, the sediments will cause an oxygen sag of only 0.5 to 0.8 mg/l from saturation conditions at several points in the River.

   c. If all the sediment deposits were of the quality found at Leavittsburg, the sediments would have a negligible impact on the stream's dissolved oxygen levels at critical low flow conditions.

   d. Under present conditions of sediment quality and point wastewater releases, the sediments exert 20 to 29 percent of the oxygen demand stabilized by the natural reaeration capacity of the river from River Mile 46.2 to 1.7 during the OEPA winter and summer minimum releases.

e. If it is assumed that the presently contemplated control strategy for point wastewater releases achieves a 78 percent reduction of oxygen demanding materials with the sediments returning to a quality found at Leavittsburg (which results in a 46 to 37 percent reduction of the sediment oxygen demand under the critical low flow winter and summer conditions), then the sediments will exert 41 to 55 percent of the total oxygen demand stabilized by the natural reaeration capacity of the river from River Mile 46.2 to 1.7.

f. The predicted result for the dissolved oxygen sag during the OEPA summer minimum low flow agrees closely with the conclusion derived with a water quality model utilized by the U.S. EPA. The results of this investigation suggest that the regulatory agencies should re-examine the OEPA winter and summer flows. The investigation also suggests that the allowable temperature maximums during the OEPA winter minimum flow period could be established at lower values to overcome pronounced dissolved oxygen sags.

5. An examination of the pollutant release rates from the bottom sediments during the critical low flow condition indicated that only iron and possibly silver could be released at such a rate as to violate their respective water quality standards of 1.0 and 0.001 mg/l. In the case of iron, an actual violation is considered unlikely since instream oxidation and re-precipitation will probably occur.

6. Turbidity:Suspended Solids Sediment quality relationships were utilized to examine the probability of water quality standard violations at elevated flow conditions. At flow regimes above the OEPA summer minimum, violations of only three (copper, lead, and zinc) of the fourteen parameters would be predicted at River Mile 13.8 with measured turbidity values (15 to 50 units) and the assumed turbidity to suspended solids ratio of 1 to 2. Suspended solids concentrations of 100 to 500 mg/l gave violations of the oil and grease, mercury and silver water quality standards, with suspended solids concentrations of 500 to 1,000 mg/l causing a violation of the chromium water quality standard. Suspended solids concentrations in excess of 1,000 mg/l were considered highly unlikely and thus no violation of the phenol, cyanide, arsenic, barium, cadmium, iron, and manganese water quality criteria was predicted at this station.

A return to the sediment quality characteristics found at Leavittsburg would result in no water quality standard violations at any flow regime; the lowest suspended solids concentration that would cause a violation would be 2,700 mg/l at which time, lead levels would be in violation of the 0.04 mg/l standard.

7. The predicted violations refer to concentrations of total materials as stated in the standards. In practical terms, the soluble fraction derived from the sediments is of most importance in toxicity considerations, and the study shows that soluble concentrations appear to be of much lower value than would be of concern.

8. Sediment transport considerations were approximated using the "Tractive Force" method of analysis. This technique, as qualified by its application to a river with a series of dams and pools, yielded a predicted mass of 83,000 to 210,000 tons that is potentially resuspended annually. This is in comparison to the annual sediment load of 1.2 million tons that has been estimated for the Mahoning Watershed. Of this total, less than five percent is associated with current urban sediment sources. It was concluded that any urban pollution control strategy would have little impact upon the mass of sediments found in the watershed.

9. Available data for current and proposed releases of cyanide, phenol and suspended solids, yielded the conclusion that, with 90 percent removal of the 1970 sediment load from point urban sources and the contemplated pollutant control strategy, only 20 to 54 percent of the present pollutant load derived from urban sources could be eliminated from the sediments. In order to achieve a future sediment quality equal to the background condition at Leavittsburg, control of non-point urban sources would have to be effected.

10. The 1970 total sediment load was estimated at 1,253,000 tons/year. If it is assumed that thirty to fifty percent of this bed load remains to fill the volume associated with 370,000 tons potentially dredged from the Mahoning, then the dredged volume could be replaced within about 10 to 16 months.

III. FORMULATION OF ALTERNATIVES

A. GENERAL

The purpose of this section is to develop a number of alternative measures which either by themselves or in combination with others can result in the formulation of possible plans for the solution of the environmental problem of the sludges and oil-soaked banks. To the degree possible, the various alternatives have been developed and evaluated according to the Water Resources Council's "Principles and Standards for Planning Water and Related Land Resources" (as published in the Federal Register, Volume 38, No. 174, Part III, dated 10 September 1973) and the Corps of Engineers policies and procedures for implementing the Principles and Standards (as published in the Federal Register, Volume 40, No. 217, Part II, 10 November 1975).

B. POSSIBLE SOLUTIONS

1. Measures Considered

The measures considered involve various structural and nonstructural alternatives as well as the "no action" measure, as presented in Table 20.

2. Preliminary Screening

All measures were subjected to a preliminary screening on the basis of (1) engineering practicability, (2) capability of providing adequate solution, (3) significant adverse impact on resource users, and (4) needs of each of the twelve river reaches. Each measure is described and presented in the form of a matrix in Table 22. Following a preliminary screening, the most feasible alternatives are considered further in greater detail in Section C of this chapter.

a. No Action

In the "No Action" alternative, no positive physical measures are taken to remove or reduce the impact of the sludge deposits or the oil-soaked banks. In most environmental problems, taking no action usually results in intensification of an existing problem. In this case, however, the no action alternative is worthy of consideration, since:

TABLE 20

MEASURES CONSIDERED

A. No Action.

B. Structural:

1. Dredging river bottom sludges.
2. Excavating oil-soaked banks.
3. Disposal of material in landfill sites.
4. Offstream treatment and recovery of material.
5. Sealing bottom deposits and oil-soaked banks in-situ.
6. Removal of low head dams.
7. Regulation of flow releases from major reservoirs to flush sediments and prevent future sedimentation.

C. Nonstructural:

Control of urban discharges.

(1) The sludges and oil-soaked banks have a relatively minor impact on water quality compared with other sources.

(2) The impact of the sludge deposits tends to diminish with time, as natural degradation takes place.

On the other hand, the existing sludge deposits have some effect on water quality and stream biology, and are aesthetically objectionable. This alternative will be evaluated in greater detail.

b. Structural Solutions

(1) Dredging River Bottom Sludges

Since sludges are found in Reaches 3 through 12 which exceed the EPA criteria for polluted sludge materials, this measure can be used in each of these Reaches. Due to the shallow nature of much of the river, a small pipeline dredge would seem to be the most suited, although in a few locations shore-operated draglines might be most suitable.

(2) Excavating Oil-Soaked Banks

Oil-soaked banks were found to occur in Reaches 5 through 10. This oil-soaked material can best be removed using draglines or other earth grading machinery. The removal of the oil-soaked banks would require the grading of stable banks having a slope of not steeper than 2:1, and this would require the removal of more soil material than that necessary to remove the oil-soaked material alone. In addition, much of the vegetation to at least the ordinary high water mark would have to be removed. Where excavation would be shallow, larger trees could be preserved. Since the Mahoning River is tree-lined for much of its length, the impact in terms of costs, aesthetics, and environment could be high.

(3) Disposal of Material in Landfill Sites

River bottom sludges and oil-soaked bank material would be disposed of in landfill sites located above the 100 year flood plain. Since this material is polluted, it would have to be contained to prevent the contamination of ground and surface water. A number of sites have been located which could serve as potential containment areas for the dredged material.

(4) Offstream Treatment and Recovery of Material

The bottom sludges and oil-soaked banks material are relatively high in iron (10%-40% on a dry weight basis). Colerapa Industries "mined" iron from the Mahoning River during 1963-1967. The iron-bearing sludge recovered contained about 65% iron by weight, which is a high quality iron residue. Although the operation was not a profitable one, the basic costs of processing and a portion of the dredging costs were defrayed by the sale of the iron. This alternative would have the following advantages over disposal in a landfill:

a. Lower overall costs.

b. Recovery of at least one usable resource.

c. Reduced quantity to be disposed of in landfill sites.

(5) Sealing Bottom Deposits and Oil-Soaked Banks In-Situ

This measure would involve the sealing of the bottom sludges and oil-soaked banks with an impermeable material to prevent the pollutants from entering the water. Such a sealant must be durable enough to withstand a rather rigorous physical abuse from the flow of the river. Flowing water erodes and carries debris which can damage sealants. Sealants have historically been used in ponds, lakes, and lagoons but not in flowing water situations. In addition to being more easily damaged in a flowing water situation, sealants are also more difficult to apply.

Sealants examined were: (1) water-borne, (2) polymeric liners, (3) asphalt, and (4) soil-cement liners. These are briefly described as follows:

Water-Borne Sealants - Water-borne sealants are materials which can be added to water and are deposited by natural action on the bottom of the river. Such materials include bentonite clay, fly ash, various silts, and polymers. Water-borne sealants can only be used for the submerged sludge deposits, not the exposed oil-soaked banks. All water-borne sealants have the problem of obtaining a uniform application in flowing waters, particularly on the steeper side slopes of the river.

Dowell, a division of Dow Chemical has developed a polymer-bentonite-polymer seal which is applied in three steps. A polymer is first introduced to the water to coat the bottom layer. Next bentonite clay is added. The bentonite combines with the polymer to form a tight bond. Finally another layer of polymer is applied to form a top bond. The manufacturer did not recommend this system for the Mahoning, however, due to the oily nature of the sludges and the dynamics of a river system eroding the material. Bentonite clay used alone would also have the same disadvantage as the polymer-bentonite combination. At best, a water-borne sealant would provide only temporary partial benefits.

Polymeric Liners - Polymeric liners have been used as sanitary landfill liners. The Environmental Protection Agency, in a report entitled "Liners for Land Disposal Sites" (SW-137), lists a number of acceptable liners such as PVC, butyl rubber, and hypalon. Plastic and rubber membranes can be fabricated with reinforcing scrim laminated between layers. Nylon and fiberglass are examples of reinforcing fabrics.

Polymeric liners can conceivably be installed on the banks and bottom without lowering the water level of the river. All trees and vegetation would require removal in order to install the liner. If the liners are kept within feasible dimensions of thickness and weight, they could be easily subject to puncture. The costs for installing such liners would be in the range of $4-$6 per square yard (20-30 million dollars total cost). Finally, the wisdom of having a continuous sheet of elastomer lining along both banks of the river could be questioned just from the aesthetic standpoint.

Asphalt and Soil-Cement Liners - Asphalt and soil cement liners are not feasible for use in the Mahoning. They are mentioned only because both materials have been used as liners for various water containers. However, there is yet no technology which would permit application of these liners in flowing river conditions. Even if they could be applied in flowing river conditions, it is doubtful that they could be applied over the existing oil-soaked bank and bottom material.

All of the materials described have been used to contain fluids. Their successful use in static water situations such as lakes, ponds, and lagoons is well documented. The problems of application and durability in a river system are not easily overcome. The nature of the bottom and bank materials pose yet additional problems for the use of sealants, and the preliminary cost estimates appear prohibitive. Therefore, sealants were rejected from further consideration.

(6) Removal of Low Head Dams

A substantial portion of the sludge material accumulates in the pools created by the 12 low head dams. Removal of these dams would result in increased velocity and a reduction of sedimentation.

Most of the pools created by the dams are currently used by industry as a source of cooling water and, therefore, could not be removed. The Lowellville dam at River Mile 13.0 is not now used by industry and could be removed. In addition two partial dams at River Mile 6.9 and 21.1 might also be removed with no adverse impact on industrial users.

Some stabilization is afforded these polluted materials by being "captured" by the dams. Removal of the dams would allow water-borne pollutants to move further downstream. The elimination of the pools would, however, improve the reaeration characteristics of the stream, which would accelerate the self-purification of the river. Before any dams are removed, the deposits behind the dams should be removed (particularly behind the Lowellville dam) to avoid downstream movement of the accumulated sludge deposits.

(7) Regulating Flow Releases to Flush Sediments and Prevent Sedimentation

As seen in the previous chapter, the natural annual flow of the Mahoning resuspends and replaces between 22 to 57 percent of the materials in the River annually. Although these sediments are removed naturally, they are replaced by the large upstream load in addition to the load from the numerous point sources. It was also shown in the previous Chapter that flows equal to or greater than 600 cfs as measured at Lowellville resulted in turbidity levels above 15, which would indicate resuspension with little sedimentation.

It is also known that this flow would not prevent sedimentation in slower flowing water situations as exist along the banks and immediately behind low head dams. Even if flows were substantially increased and maintained above 600 cfs, there would still exist slackwater areas which would not be scoured and would allow some sedimentation to occur. Therefore, it would be necessary to remove the low head dams and construct a channel which would convey the flow of the river so that solids deposition would not occur to achieve complete control of sedimentation.

This alternative can be addressed using the Tractive Force Methodology summarized in Figure 14 of Chapter II to determine a stable cross section. Table 21 summarizes the postulated conditions for such an

TABLE 21

APPROXIMATE CROSS-SECTION AT YOUNGSTOWN GAGE
FLOWS TO PREVENT SOLIDS DEPOSITION

Flow Regime	Flow (cfs)	S = 0.0001 Ft/Ft		S = 0.0004 Ft/Ft	
		Width (ft)	Mid-Point Depth (ft)	Width (ft)	Mid-Point Depth (ft)
Guaranteed Winter Low	240	40	16.5	40	4.2
Guaranteed Summer Low	460	55	16.5	65	4.2
Average Minimum Month*	390	50	16.5	60	4.2
Average* JASO	510	60	16.5	75	4.2
Average* Annual	860	75	16.5	115	4.2
Average* FMAM	1,390	95	16.5	175	4.2
Average Maximum Month*	1,720	105	16.5	215	4.2
Maximum Month*	2,540	125	16.5	310	4.2

*October, 1968 through September, 1973.

alternate for two stream slopes with the normal year's flow variation at the Youngstown Gage. Ideally, one would construct a basic concrete structure with the overall physical dimensions described for the guaranteed minimum water flow with appropriate sidewalls above the 16.5 foot winter low mid-point depth to assure the attainment of a velocity greater than or equal to that predicted with the higher flow ideal cross-sections up to maximum flood stage. With a record maximum some ten times greater than the average maximum month, this would indeed be a strange structure. In terms of aesthetics alone, the cure to totally eliminate sediment deposition would be worse than the sediments themselves. Also, the cost of this alternative would be far beyond any reasonable assessment of benefits. Therefore, this alternative is eliminated from further consideration.

c. Non-Structural Solutions

The only non-structural solution considered feasible was the control of urban discharges. This measure is the most effective solution for improving the overall water quality of the Mahoning River. The previous chapter showed that if the sediment in the Mahoning were of a quality equal to that at Leavittsburg, there would be little impact on water quality as a result of sediments. The difference in quality between the sediments at Leavittsburg and the sediments downstream is the heavy concentration of pollutants attributable to the municipal and industrial point and non-point discharges in the Warren-Youngstown area. In order for any of the previously discussed measures to be permanently successful, the urban point sources, combined sewer discharges, and storm flows must be controlled to a far greater degree than they are currently.

Table 22 shows in summary form the results of the preliminary screening of alternatives. This screening resulted in the elimination of in-situ sealing, dam removal in most reaches and flow regulation. Retained for further detailed evaluation are no action, excavation and dredging of materials, landfill and treatment of materials removed, selected dam removal, and urban discharge control.

C. EVALUATION OF MEASURES CONSIDERED FURTHER

Based on the preliminary screening, the following feasible alternative measures will be considered further:

1. No Action

2. Dredging Alternatives:

    a. Dredging bottom sludges in Reaches 3 and 12.
    b. Excavating oil-soaked banks in Reaches 5 through 10.

TABLE 22

PRELIMINARY QUALITATIVE SCREENING

Measures	River Reaches 1	2	3	4	5	6	7	8	9	10	11	12	Result of Preliminary Screening
NO ACTION													Retain
STRUCTURAL													
Dredging sludges	4	4											Retain
Excavating oil-soaked banks	4	4	4	4									Retain
Disposal in landfills	4	4									4	4	Retain
Offstream treatment	4	4											Retain
Sealing bottom sludges and banks	4	4	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	Reject
Removal of low head dams (dam at downstream end of reach)	4	4	3	3	3	3		3	3			4	Retain for Reaches 7, 10 & 11
Regulate flow releases from upstream reservoirs	4	4	1,3	1,3	1,3	1,3	1	1,3	1,3	1	1	1	Reject
NON-STRUCTURAL													
Control Urban Discharges	4	4									4	4	Retain

Numbers in table refer to the reasons for rejection listed below:

1. Engineeringly impracticable
2. Incapable of providing adequate solution
3. Significant adverse impact on resource users
4. No major need

3. Disposal Alternatives

   a. Landfill sites.
   b. Off-stream treatment and iron recovery.

4. Removal of low head dams at River Miles 6.9, 13.0, and 21.1.

5. Urban Discharge Control.

1. No Action

In the no action alternative, it is assumed that the sediments and oil-soaked banks are allowed to remain. As was discussed in Chapter II, all sludges downstream of Copperweld Steel are several times more polluted than the EPA criteria for polluted sediments, when removed from the river and analyzed in the laboratory. From the standpoint of impact on water quality, however, only dissolved oxygen in Reaches 10 and 11 and iron in Reaches 1, 2, 3, 4, 9, 10, 11 and 12 would fail to meet water quality standards as a result of sediment impact under worst case low flow conditions. Since worst case conditions represent the extreme, the probability of occurrence is very low. During high flow conditions, violations of Warm Water Fisheries Standards for only three parameters (copper, lead and zinc) are likly to occur. However, the standards are stated in total concentrations, and the analysis reported in Chapter II show that the heavy metals are largely bound up in the sediment solids. The soluble fraction, which is of concern from the standpoint of toxicity, is very low.

2. Dredging Alternatives

a. Dredging Bottom Sludges in Reaches 3 through 12

Reaches 3 through 12 contain substantial quantities of sludge material which exceeded the EPA criteria for polluted sludges by factors ranging from 2.7 to 18.0. Although there is some sludge material accumulated in Reach 2, no analyses were performed to determine its quality characterization. An analysis was performed on the sludge material at the Leavittsburg Dam, approximately four miles upstream from the deposits in Reach 2, and was determined to be unpolluted as judged by the EPA standards. Since there are no significant point discharges between the Leavittsburg Dam and the sludges in Reach 2, it is assumed that the material in Reach 2 is also unpolluted.

Under this alternative, bottom sludge material would be removed using a hydraulic pipeline dredge. Because of the varying depth of flow in the river due to the dams, and the rock bottom of the channel in various areas, the use of a large barge, such as generally operates in navigable rivers cannot be considered. The sludge material would be piped to 3 to 5 multi-celled temporary settling basins located along the river with easy access to highways. It is estimated that the sludge material would be diluted during the dredging process from approximately 40% solids by weight to 20-25% in the process of dredging. The sludge would probably require a period of several weeks to settle and consolidate in order to be concentrated enough for truck transport to either a landfill site or a treatment facility. The sludge is expected to concentrate to about 70% solids dry weight after storage in the basins.

The settling basins can be excavated from adjacent flood plain land. Topsoil would be removed and stored for use when the area is restored to its former condition. The land would be graded to form a rectangle having dikes at the edges with an enclosed area sloping gently toward the river. At approximately ten foot intervals, french drains consisting of coarse gravel covered with slag screenings would be constructed in the floor of the basin. These drains would lead to a collector channel of similar construction formed along the base of the dike parallel to the river, to permit the separated water to return to the river. Each cell would be on the order of 100 to 200 feet on the sides and from 5 to 10 feet deep. A bank of cells in one location would facilitate handling the pipeline and centralize the loading and hauling operation.

It is anticipated that the leachate would contain suspended solids in the range of 500 mg/l, and would be allowed to return to the river. Should this concentration prove to be excessive, a separate settling basin could be provided which would allow the liquid to settle and the supernatant could discharge to the river via a sand filter. It is expected that each cell would be utilized several times until the pipeline length becomes excessive and closer cell sites become economically desirable.

The material from the cells would be removed and loaded into trucks for transport to the final disposal site. Front end loaders or backhoes would be used within the basins, with dump trucks driving on ramps formed on the dewatered sludge in order to reach the excavating apparatus. Dragline loading might be a feasible alternative loading method.

It is estimated that all of the bottom sludge would be removed in a one year period amounting to approximately 250 working days. This would mean the daily removal of about 1,150 cubic yards of sludge as measured in place, or 2,300 cubic yards of diluted sludge pumped out of the river and into the dewatering cells. The haul-away volume would be on the order of 510 cubic yards, approximately 720 tons. If this rate of removal cannot be attained by a single dredge, it may be more economical to extend the working period rather than utilize a second dredge and pipeline.

After hauling is completed, the dewatering cell sites would be regraded, with the topsoil replaced, and the area revegetated. It is assumed that open areas would be utilized and that tree removal would be minimal.

The dredging operation would commence at the furthest upstream point and continue downstream until completed in order to avoid any contamination of a previously dredged portion. An oil boom would be placed downstream of the dredge to contain any oil released from the bottom sludges. An oil skimmer would be used to remove the oil from the water surface and deposit it in containers for disposal.

Construction access easements would be required covering the entire width of the river. Access easements would also be required to allow entrance of the dredge and associated equipment and to permit the equipment to be moved around low head dams. Generally, the dredge would be able to excavate its own channel in shallow water areas. However, it may be necessary to remove the dredge from the water in some sections to move around shallow sections. Easements would also be required for the location of temporary settling basins. In all cases, the land use for temporary easements would be regraded and restored to its former condition.

The costs by River Reach for dredging the sludges are presented in Table 23. It is assumed that easements would be granted to the United States Government without charge only for the land beneath the river. Access easements, bank easements, and all other easements would be purchased.

b. Excavating Oil-Soaked Banks in Reaches 5 through 10

About 23.8 miles of the Mahoning River have extensive oil-soaked banks. The total estimated volume of oil-soaked material is 285,600 cubic yards. If the oil-soaked banks were to be totally removed, the banks would have to be regraded to a stable condition to limit erosion. Thus a greater quantity of material would have to be removed to provide suitable side slopes. Assuming an irregularly shaped oil-soaked bank material having almost a vertical face at the normal water's edge, and assuming that a two-to-one side slope would be required to provide

TABLE 23

ESTIMATED DREDGING COSTS
BOTTOM SLUDGES ONLY

Reach No.	Sludge Volume Cu. Yds.	(1) Easements $	Dredging $	(2) Basins $	Total Const. Costs $	(3) Eng. and Design $	(3) Supervision and Admin. $	Total Capital Costs $	$/Cu. Yd.
3	8,700	3,000	21,800	13,050	37,850	4,500	3,800	46,150	5.30
4	5,000	2,000	12,500	7,500	22,000	3,200	2,600	27,800	5.56
5	213,800	30,000	534,500	320,700	885,200	47,000	68,400	1,000,600	4.68
6	11,800	5,000	29,500	17,700	52,200	6,100	5,400	63,700	5.40
7	9,000	4,000	22,500	13,500	40,000	4,700	4,300	49,000	5.44
8	7,600	5,000	19,000	11,400	35,400	4,600	4,100	44,100	5.80
9	7,600	4,000	19,000	11,400	35,400	4,600	4,100	44,100	5.80
10	17,500	7,000	43,700	26,250	76,950	7,700	8,000	92,650	5.29
11	3,400	4,000	8,500	5,100	17,600	2,200	1,900	21,700	6.38
12	3,400	4,000	8,500	5,100	17,600	2,200	1,900	21,700	6.38
TOTALS	287,800	68,000	719,500	431,700	1,220,200	86,800	104,500	1,411,500	

Average Cost/Cu. Yd. - $4.90

(1) Costs of easements for dredging access and dewatering basins.
(2) Dewatering basins, cost of construction and restoration.
(3) Engineering and Design and Supervision and Administration are not applied to easements.

stable banks under varying water levels, it is estimated that an additional ten cubic feet of unpolluted bank material above and below the normal water line would have to be removed on each side of the river for each linear foot of river. This additional excavation of unpolluted bank material would amount to four thousand cubic yards per river mile or a total of 95,200 cubic yards of unpolluted material to be removed. Thus, the total excavation involved with removing oil-soaked material is on the order of sixteen thousand cubic yards per river mile or 380,800 cubic yards for the 23.8 miles. A typical bank cross section with a 2:1 slope following excavation is shown in Figure 16.

In addition, most of the vegetation would be removed on the sides of the river for an overall width of approximately 50 feet (25 feet on each side) to permit the excavation and movement of construction equipment. Since the river bank contains many trees, the regrading operation would require removal of a substantial number of trees where the cut exceeds two or three feet.

Bank excavation and regrading would be performed from both sides of the river using draglines and bulldozers. An oil boom would be placed around each construction area to contain any oil released during the excavation. The oil would be removed from the water using an oil skimmer and stored in drums for ultimate disposal. The excavated oil-soaked material would be transported directly either to landfill sites or the treatment facility. No dewatering would be required.

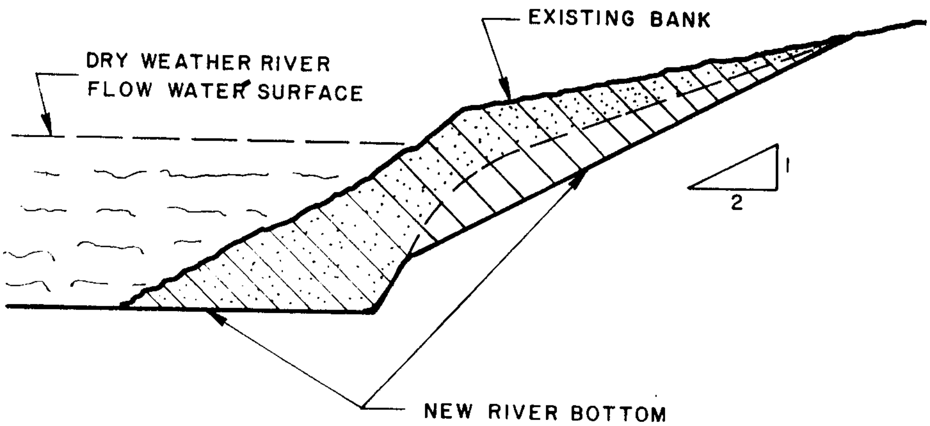
The river banks would be seeded with species of grasses such as creeping red fescue, Kentucky bluegrass, redtop, timothy and birdsfoot trefoil to retard erosion. In order to restore wildlife habitat, various native tree and shrub plantings would also be made.

The costs by River Reach for removal of the oil-soaked bank material are presented in Table 24.

3. Disposal Alternatives

a. Landfill Sites

The landfill ultimately becomes the common reservoir of the majority, if not all, the dredged materials. A preliminary reconaissance of the area was made to locate existing landfills which are suitable for receiving the dredged material. A private landfill was located near Salem, Ohio, which is located in a strip mine area.



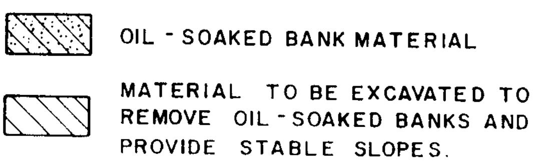


FIGURE - 16

TYPICAL BANK CROSS SECTION

MAHONING RIVER STUDY
DEPARTMENT OF THE ARMY
PITTSBURGH DISTRICT, CORPS OF ENGINEERS

TABLE 24

ESTIMATED DREDGING COSTS
OIL-SOAKED BANKS ONLY

Reach No.	Sludge Volume Cu. Yds.	(1) Easements $	(2) Bank Clearing $	Excavation $	Total Const. Costs $	(3) Eng. and Design $	(3) Supervision and Admin. $	Total Capital Costs $	$/Cu. Yd.
5	156,800	22,000	98,000	548,800	668,800	38,800	51,700	759,300	4.84
6	60,800	8,000	38,000	212,800	258,800	18,800	23,800	301,400	4.96
7	33,600	5,000	21,000	117,600	143,600	13,900	15,200	172,700	5.14
8	46,400	7,000	29,000	162,400	198,400	15,300	19,000	232,700	5.02
9	30,400	5,000	19,000	106,400	130,400	12,500	13,800	156,700	5.09
10	52,800	7,000	33,000	184,800	224,800	17,400	21,800	264,000	5.00
TOTAL	380,800	54,000	238,000	1,332,800	1,624,800	116,700	145,300	1,886,800	

Average Cost/Cu. Yd. - $4.95

(1) Costs of easements for access to river banks and 30' wide strip of land on either side of river.
(2) Costs of tree removal on both banks.
(3) Engineering and Design and Supervision and Administration are not applied to easements.

Although this landfill area does not yet have a permit to operate from the Ohio Environmental Protection Agency, Ohio EPA has given a preliminary indication that the site would be acceptable for the disposal of the Mahoning River dredgings. The area is relatively impervious with all drainage leading to a common lagoon. Leachate would be monitored and if found to be unacceptable for surface discharge, would be treated. The major problem with this private landfill site is its distance from the Mahoning River, (about 20 to 25 miles).

The Mahoning Valley area was also surveyed for vacant land which might be utilized for closer landfill sites. The Eastgate Development and Transportation Agency's Existing Land Use Maps and 1990 Generalized Land Use Map were used to locate areas which are now vacant and are projected to remain vacant in the future. Land areas were only considered if they were located outside of the 100 year flood plain. A number of areas meeting these criteria were identified, and are shown along with the private landfill site in Figure 17.

The dredged materials must be disposed of in a manner which would not result in the contamination of surface or groundwater. New landfill sites should have a substrate of impervious material and should be covered with material of low permeability to minimize the entrance of rainfall. The natural clays in the Mahoning Valley are generally suitable for this purpose. The soils are primarily the Mahoning type which have a relatively high available moisture capacity *(0.1 to 0.2 inches of water per inch of soil) and a low permeability rate **(0.063 to 0.2 inches per hour). Under low intensity short duration rainfall periods, the soil has a high capacity to store water without runoff or infiltration. Under more intense short duration rainfall periods, water will tend to run off with little infiltration to the landfill materials. Under low intensity long duration rainfall periods, once the available moisture capacity has been exceeded, a substantial portion of the total rainfall will infiltrate. The Mahoning soils, as well as other soil types, have a range of values for any given characteristic. Should the project be implemented, detailed soil testing would be conducted to obtain more specific information.

*Available moisture capacity - defined by USDA as the amount of water which will wet air dry soil to a depth of 1 inch without deeper percolation.

**Permeability - defined by USDA as the rate of downward movement of water in inches/hour under saturated soil conditions.

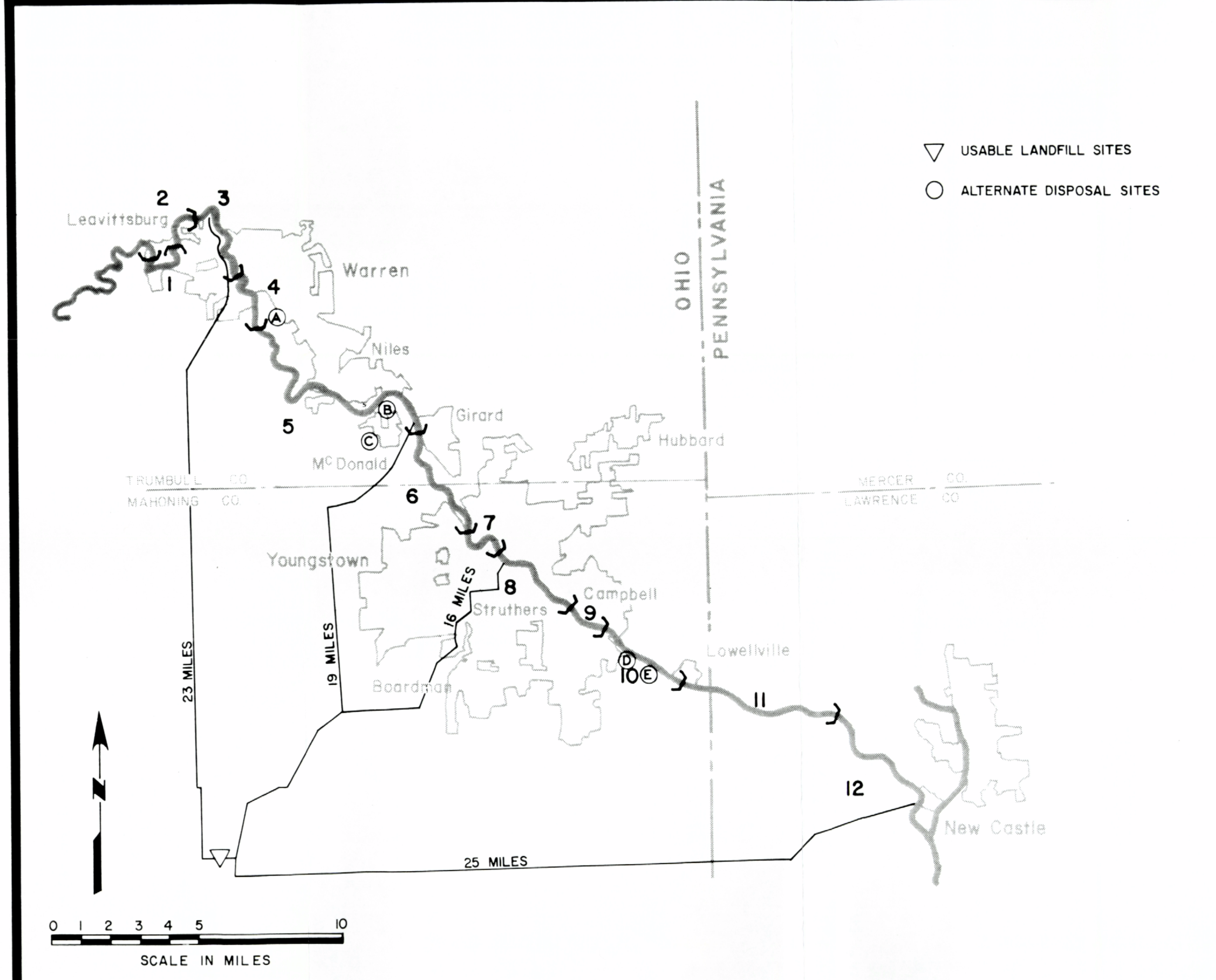


FIGURE - 17
PROPOSED ALTERNATE DISPOSAL SITES
MAHONING RIVER STUDY
DEPARTMENT OF THE ARMY
PITTSBURGH DISTRICT, CORPS OF ENGINEERS

It is proposed to excavate the landfill areas to allow the deposition of sludge to a depth of 5 feet. Approximately 80 acres of land would be required for disposal. French drains would be located in the landfill area to capture any leachate which would be produced. All surface drainage would be diverted around the landfill and an overlying layer of clay and topsoil would be used to reduce rainwater infiltration. If rainwater and surface water infiltration is minimized, the leachate production would be insignificant in quantity. The leachate would be diverted back to the Mahoning River via a ditch or pipe. With the above precautions, it is believed that the leachate load to the river would be small enough so as not to require treatment to meet river water quality standards.

Tables 25 and 26 present the costs for disposal of bottom sludges and bank materials by River Reach at both nearby new publicly owned sites and the more distant existing private site. These costs include the cost for loading from the settling basin, transportation to the site, and disposal in the case of bottom sludges, and include the transportation and disposal costs for the bank material. The costs are based on the assumption that the native clay material would be acceptable for an impervious layer, and that treatment of the leachate would not be required. As seen in these two tables, the least cost disposal alternative for each reach is the nearby new landfill sites.

If monitoring indicates that the leachate requires treatment, a treatment plant comprising storage facilities to hold the leachate, carbon dioxide stripping, single stage lime treatment, and clarification would be installed. The plant would be designed to handle the leachate volume produced by the 1 year - 24 hour storm (the 1 year storm with the greatest potential for maximum infiltration). The storage lagoon would be large enough to hold the leachate from the 1 year - 24 hour storm and feed this volume through the treatment process over a 14 day interval. Air would be diffused into the storage lagoon at a rate of between 0.05 to 0.1 cubic feet/gallon to provide carbon dioxide stripping.

The flow would then be conveyed to a single stage flash mix tank where lime would be added to a concentration of 300 mg/l and allowed to mix for 5 minutes. The leachate would then be allowed to settle to remove the pollutants.

Table 27 presents estimated capital and operation costs for the five treatment facilities, which correspond to those new landfill sites identified in Figure 17. The assumption made was that 25% of the average annual rainfall (35 inches/year) would infiltrate the landfill. It was also assumed, based on the characteristics of the

TABLE 25

ESTIMATED DISPOSAL COSTS
BOTTOM SLUDGES

Reach No.	Sludge Volume Cu.Yds.	Disposal Site	Distance to Site Miles	(1) Load and Haul $	(2) Land Costs $	(3) Existing Private Landfill Costs $	(4) Construction Costs $	(5) Engr. and Design $	(6) Super-vision and Admin. $	Total Project Costs $	$/Cu. Yd.
3	8,700	New Publicly Owned	3	11,700	1,500		2,400	600	1,800	18,000	2.07
		Existing Private	21	43,000		11,600			5,400	60,000	6.90
4	5,000	New Publicly Owned	1	4,800	900		1,400	300	800	8,200	1.64
		Existing Private	20	23,700		6,700			3,100	33,500	6.70
5	213,800	New Publicly Owned	2	245,900	36,400		57,700	7,200	30,400	377,600	1.77
		Existing Private	18	930,000		284,400			79,000	1,293,400	6.05
6	11,800	New Publicly Owned	3	15,900	2,000		3,200	800	2,500	24,400	2.07
		Existing Private	17	49,000		15,700			5,600	70,300	5.96

TABLE 25

ESTIMATED DISPOSAL COSTS
BOTTOM SLUDGES (CONT'D.)

Reach No.	Sludge Volume Cu.Yds.	Disposal Site	Distance to Site Miles	(1) Load and Haul $	(2) Land Costs $	(3) Existing Private Landfill Costs $	(4) Construction Costs $	(5) Engr. and Design $	(6) Super-vision and Admin. $	Total Project Costs $	$/Cu. Yd.
7	9,000	New Publicly Owned	5	15,800	1,500		2,400	600	2,400	22,700	2.52
		Existing Private	16	35,600		12,000			4,300	51,900	5.77
8	7,600	New Publicly Owned	4	11,800	1,300		2,100	500	1,800	17,500	2.30
		Existing Private	16	30,000		10,100			3,700	43,800	5.76
9	7,600	New Publicly Owned	2	8,700	1,300		2,100	500	1,500	14,100	1.86
		Existing Private	18	33,000		10,100			4,100	47,200	6.21
10	17,500	New Publicly Owned	1	16,600	3,000		4,700	1,200	2,700	28,200	1.61
		Existing Private	19	79,600		23,300			8,800	111,700	6.38

TABLE 25

ESTIMATED DISPOSAL COSTS
BOTTOM SLUDGES (CONT'D.)

Reach No.	Sludge Volume Cu.Yds.	Disposal Site	Distance to Site Miles	(1) Load and Haul $	(2) Land Costs $	(3) Existing Private Landfill Costs $	(4) Construction Costs $	(5) Engr. and Design $	(6) Super-vision and Admin. $	Total Project Costs $	$/Cu. Yd. $
11	3,400	New Publicly Owned	3	4,600	600		1,000	300	800	7,300	2.15
		Existing Private	20	16,100		4,500			2,000	22,600	6.65
12	3,400	New Publicly Owned	8	8,000	600		1,000	300	1,200	11,100	3.26
		Existing Private	25	19,500		4,500			2,500	26,500	7.79
TOTALS	287,800	New Publicly Owned		343,800	49,100		78,000	12,300	45,900	529,100	
		Existing Private		1,259,500		382,900			118,500	1,760,900	

Average Cost/Cu.Yd. New Publicly Owned 1.84
Existing Private 6.12

(1) Costs to load from dewatering basins and transport to landfill.
(2) Land costs for new publicly owned landfills.
(3) Costs based on charges by existing privately owned landfills.
(4) Costs for construction of new publicly owned landfills.
(5) Engineering and design costs applied to item (4).
(6) Supervision and administration costs applied to items (1) and (4).

TABLE 26

ESTIMATED DISPOSAL COSTS
OIL-SOAKED BANKS

Reach No.	Sludge Volume Cu.Yds.	Disposal Site	Distance to Site Miles	(1) Haul $	(2) Land Costs $	(3) Existing Private Landfill Costs $	(4) Construction Costs $	(5) Engr. and Design $	(6) Super-vision and Admin. $	Total Project Costs $	$/Cu. Yd.
5	156,800	New Publicly Owned	2	56,400	58,000		98,800	9,900	16,300	239,400	1.53
		Existing Private	18	508,000		470,400			43,200	1,021,600	6.52
6	60,800	New Publicly Owned	3	32,800	22,500		38,300	5,200	7,800	106,600	1.75
		Existing Private	17	186,000		182,400			18,600	387,000	6.37
7	33,600	New Publicly Owned	5	30,200	12,400		21,200	3,600	6,200	73,600	2.19
		Existing Private	16	96,800		100,800			10,600	208,200	6.20
8	46,400	New Publicly Owned	4	33,400	17,200		29,200	4,400	7,500	91,700	1.98
		Existing Private	16	133,600		139,200			14,700	287,500	6.20

TABLE 26

ESTIMATED DISPOSAL COSTS
OIL-SOAKED BANKS - (CONT'D.)

Reach No.	Sludge Volume Cu.Yds.	Disposal Site	Distance to Site Miles	(1) Haul $	(2) Land Costs $	(3) Existing Private Landfill Costs $	(4) Construction Costs $	(5) Engr. and Design $	(6) Super-vision and Admin. $	Total Project Costs $	$/Cu. Yd.
9	30,400	New Publicly Owned	2	10,900	11,200		19,200	3,300	3,800	48,400	1.59
		Existing Private	18	98,500		91,200			10,800	200,500	6.60
10	52,800	New Publicly Owned	1	9,500	19,500		33,300	5,000	5,100	72,400	1.37
		Existing Private	19	180,600		158,400			18,100	357,100	6.76
TOTALS	380,800	New Publicly Owned		173,200	140,800		240,000	31,400	46,700	632,100	
		Existing Private		1,203,500		1,142,400			116,000	2,461,900	

Average Cost/Cu.Yd. New Publicly Owned 1.66
Existing Private 6.47

(2) Land costs for new publicly owned landfills.
(3) Costs based on charges by existing private owned landfills.
(4) Costs for construction of new publicly owned landfills.
(5) Engineering and design costs applied to item (4).
(6) Supervision and administration costs applied to items (1) and (4).

TABLE 27

ESTIMATED CAPITAL AND OPERATING COSTS FOR TREATMENT FACILITIES

		Site A	Site B	Site C	Site D	Site E
Acres of Landfill		1.0	19.4	24.5	10.4	7.9
Plant Size (1,000's gallons)		3.9	76.0	96.0	40.7	31.0
Storage Tank Capacity (1,000's gallons) (1 year - 24 hour storm)		54.5	1,058	1,336	568	431
Total Annual Flow (1,000's gallons)		238	4,618	5,832	2,476	1,880
Land Required for Treatment Facility (acres)		.5	1	2	1	1
Real Estate Costs	$	1,000	2,000	4,000	2,000	2,000
Construction Costs	$	8,300	48,000	61,000	25,800	19,700
Engineering and Design(1)	$	1,700	6,500	7,300	3,900	3,200
Supervision and Administration(1)	$	1,100	5,500	7,000	3,200	2,400
Total Capital Costs	$	12,100	62,000	79,300	34,900	27,300
Annual Capital Costs (20 year)	$	1,000	5,300	6,800	3,000	2,400
Annual O & M Costs	$	2,700	6,800	7,200	4,700	4,500
Total Annual Costs	$	3,700	12,100	14,000	7,700	6,900
Total Costs/1,000 gallons	$	15.54	2.62	2.40	3.10	3.67

(1) Engineering and Design and Supervision and Administration are not applied to land costs.

soil, that 80% of the 1 year - 24 hour rainfall would infiltrate. These assumptions were used to estimate the costs for treatment facilities, which would be added to overall system costs if leachate treatment were proved necessary.

b. Off-Stream Treatment

Two off-stream treatment concepts were evaluated as possible alternatives or modifications to the landfill alternative. The first alternative considered was that of incinerating the sludge material. Assuming the sludge material contained 70% solids by weight, no fuel would be required to incinerate the material due to the oil and grease content. Even if the material were to contain 40% moisture at a feed rate of 5 tons per hour, only 11.34 pounds of fuel oil would be required to initiate and sustain burning.

The disadvantages of incineration are the problems associated with adding additional pollutants to the air which, in the Mahoning Valley, are excessive. Due to the high inorganic content of the sludges, incineration would do relatively little to reduce the mass of material, leaving a substantial quantity of ash to be disposed of in landfills.

The loss of sulfide and organic complexes of the heavy metals result in additional ultimate solubility of many metals in the sediments. Studies by Havens and Emerson of municipal sludges have indicated that incineration may increase the ultimate (citrate) solubility of cadmium, copper, and silver in the ash. On the other hand, the ultimate solubility of chromium, nickel, and zinc showed a decline after incineration. Only lead failed to exhibit a measureable solubility change[(1)]. Other studies by Havens and Emerson, attempting to define the gaseous metal emissions, indicate that 90 to 98 percent of the silver, copper, iron, arsenic, chromium, and nickel in a feed sludge would be retained in the ash with most of the remainder being removed in the scrubber water. This same study showed that under normal incineration operations, actual SO_x and NO_x released to the atmosphere were only on the order of 6 and 3 percent of the applied sulfur and nitrogen, respectively. The incinerator ash contained 60 percent of the applied sulfur and 6 percent of the applied nitrogen[(2)].

(1) "A Plan for Sludge Management" prepared for the Metropolitan District Commission of Boston, Massachusetts, by Havens and Emerson, Ltd. (August, 1973).
(2) "Middletown Incineration Study" internal Havens and Emerson memorandum to the record (August, 1975).

Based on the low reduction in mass, the potential problems associated with a more soluble ash, additional pollutant release to the atmosphere, and a possible auxiliary fuel demand, incineration was discarded as a viable alternative for this material.

The second treatment concept considered was that of reclaiming the iron which is found in rather substantial quantities in some of the sludges and bank material. As indicated earlier in this Chapter, the Colerapa Industries successfully extracted a material containing 65% iron from the Mahoning River sludges during 1963-1967. The process used by Colerapa, (under the Hess-von Bulow name), was to hydraulically dredge the bottom sludge and bank deposits and transport this material to a floating process plant which was attached to the dredge. The entire unit weighed 126 tons, was mobile, and floated in the river. The process plant was approximately three stories high which required dismantling when low bridges were encountered. When the water was not deep enough to float the equipment, it was necessary either to dredge a channel, create a temporary dam to raise the water level, or remove the dredge and process plant from the river to transport it around the obstruction.

The unit excavated the bottom materials, concentrating the iron "ore" which was pumped to shore by pipeline. The tailings were discharged back to the river at the rear of the process plant. Three units operated over a 16 mile reach of the Mahoning and recovered 278,000 tons of iron "ore". The average of the analyses of the reclaimed material was 69% iron and only 3% silica. Commercially available iron ore has an iron content less than 69%, with considerably more silica. However, the sale of the iron ore to the mills did not produce enough income to cover all costs involved in dredging and processing the material.

A conceptual plan for iron recovery consists of establishing a process plant in the vicinity of Reach 5, where the majority of the sludge material is located. This plant would be within 2 miles of the new publicly owned Landfill Site B or C for easy disposal of tailings. If the existing private landfill site were used, the haul distance would be about 20 miles.

Dredged material which had been dewatered to about 30% moisture in the dewatering basins would be transported to the treatment plant. The material would be treated through a process adapted from that used by Colerapa as shown in Figure 18. It is our understanding that the recovery process may be a proprietary one, or may involve some proprietary features. Costs involved in iron recovery included sur-

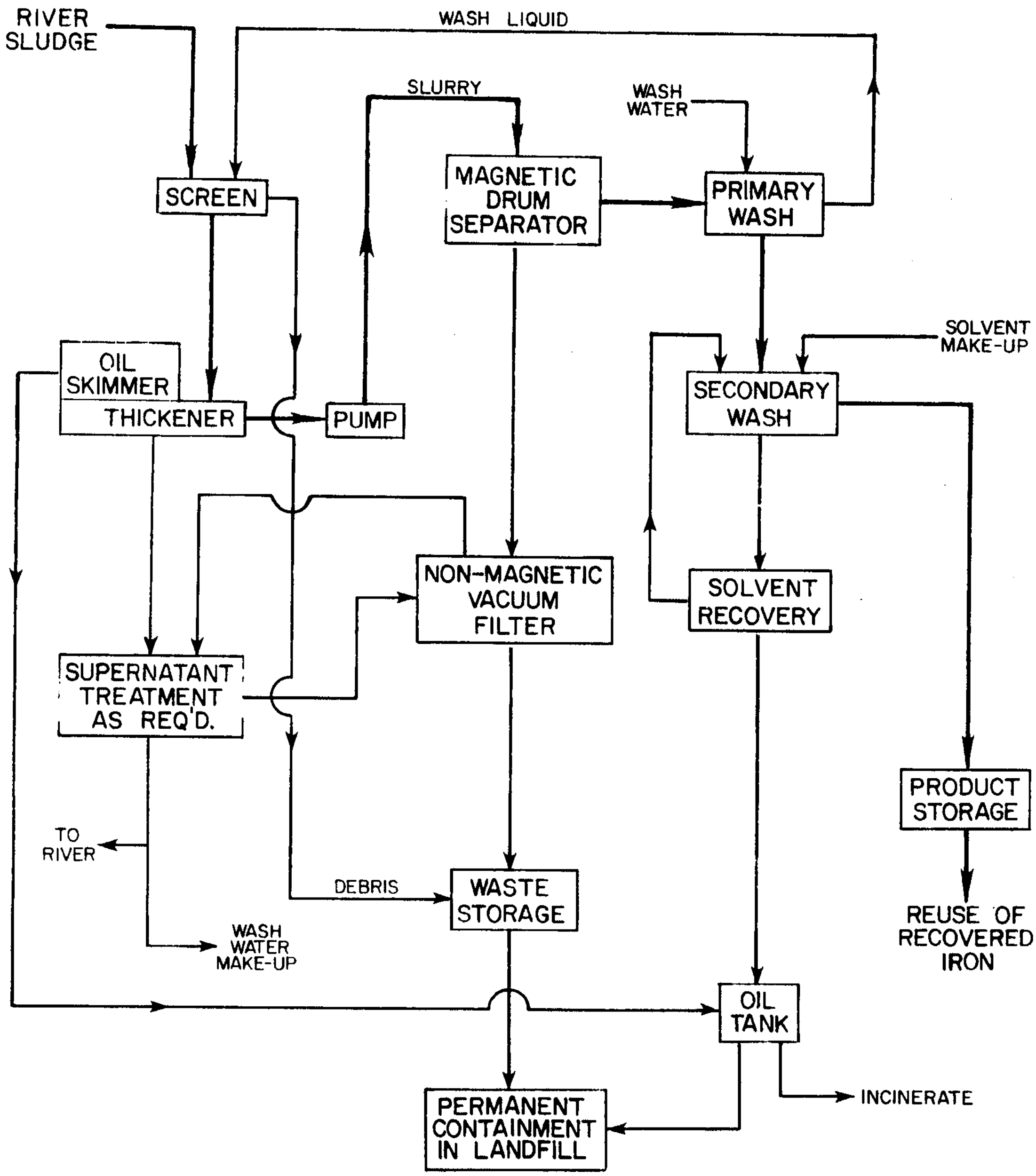


FIGURE - 18

IRON RECOVERY PROCESS

MAHONING RIVER STUDY
DEPARTMENT OF THE ARMY
PITTSBURGH DISTRICT, CORPS OF ENGINEERS

veying the bottom material for sediments high in iron, transportation of material from the dewatering basins to the process plant, processing costs, disposal of tailings, and delivery of the iron ore.

The analyses performed by USEPA, the Corps of Engineers, and Havens and Emerson found total solids in the sediment ranging from 21.8% to 80.0% with an average of approximately 40%. Iron ranged from .8% to 41.0% of the total solids. Assuming an average total solids of 40%, the total costs for recovery of iron ore would about equal the income from the sale of the ore, <u>when</u> the iron concentration is in the range of 35 to 42 percent iron.

Sludges in the river having a solids concentration higher than 40% could equal the breakeven point at a lower percentage iron than 35 to 42 percent.

It is believed that iron recovery is potentially feasible if the dredging alternative is selected, on part of the material to be dredged and excavated. Detailed surveys of the river would be required to locate material which would have a high enough iron content to be economically feasible for iron recovery.

4. Removal of Low Head Dams at River Miles 6.9, 13.0 and 21.1

Although removal of all dams in the study area was found infeasible in the preliminary screening, three of the dams might possibly be removed. The partial dams at River Miles 6.9 and 21.1 and the dam at River Mile 13.0 (Lowellville) no longer serve the original purpose for which they were built, principally industrial water supply. Sharon Steel, which used the pool created by the Lowellville dam, completely dismantled its operation several years ago. The dams now serve only as sediment traps which result in depressed dissolved oxygen levels in the pools, particularly at the Lowellville Dam.

The elimination of these dams would return approximately 5-1/2 miles of the river to a more natural state which would increase reaeration of the river. As presented in the previous Chapter (Figure 12), the most stressed portion of the river due to oxygen demand of sediments and elevated winter temperatures is Reach 10. The removal of the dam at River Mile 13.0 would substantially prevent the accumulation of sediments and the resultant impact on water quality in this reach. Prior to the removal of this dam at River Mile 13.0, the accumulated sediments would require removal. Estimated costs for dam removal are as follows:

Dam Location	Volume of Material To Be Removed Cubic Yards	Easements $	Unit Price per Cubic Yard $	Total Construction Costs $	Engr. and Design $	Supervision and Admin. $	Total Capital Costs $
River Mile 6.9	110	500	80	9,300	1,800	1,100	12,200
River Mile 13.0	220	500	80	18,100	2,900	2,100	23,100
River Mile 21.1	22	500	80	2,100	300	200	2,600
Totals	352	1,500		29,500	5,000	3,400	37,900

5. Urban Discharge Control

As indicated earlier, this alternative probably represents the most important action which could be taken to improve overall water quality of the Mahoning River. As differentiated from the no action alternative, this measure would result in the gradual improvement in sediment quality approaching the quality which exists at Leavittsburg. In the previous Chapter, it was estimated that natural movement of sediments due to river flows result in the replacement of 22 to 57 percent of the total sediment quantity per year. If point source controls are implemented to achieve the BPT requirements, then between 20 to 54 percent of the pollutant load derived from the sediments would be eliminated. In order to approach the quality of the sediments at Leavittsburg, additional control of urban non-point discharges is also required.

Even in the absence of river scour, the oil in the bottom deposits and along the river banks would undergo degradation. Oil pollutants are decomposed through evaporation, oxidation, biodegradation and dissolution.

Evaporation affects the low boiling point and low molecular weight class of hydrocarbons (the aromatics). The rate of evaporation is dependent primarily on the vapor pressure of the oil, and is enhanced by riffle action, high river temperature, irradiation, and increased surface area. Some of the components of oil evaporate more slowly than others; the residues which remain have a higher specific gravity and viscosity than fresh oil. The residues may have a specific gravity greater than the water and sink to the bottom, although this occurs more frequently when the oil is occluded to materials of a high specific gravity.

The agglomeration of oil with natural sorptive agents including organic and inorganic debris and clay minerals suspended in the water results in a blanketing of the river bottom. Once these sediments have settled, they undergo the same biological and chemical processes as other organics. The rate of decomposition by microorganisms is dependent upon the amount of decomposable matter relative to the type of microorganisms present.

More than 100 species of bacteria, yeasts, and fungi have been demonstrated to oxidize hydrocarbons. No single microbial species can utilize all hydrocarbons; each is limited in the scope of its nutritional capabilities. Limiting agents for bacteria include mineral salts, nitrogen, phosphates, pH and the presence or absence of oxygen. Some hydrocarbon oxidizers can utilize nitrate or sulfate rather than oxygen as hydrogen acceptors, but they are relatively few. Oxygen will only penetrate the accumulated sediment as deeply as the balance is maintained between oxygen diffusion and oxygen consumption; where consumption exceeds diffusion, anaerobic conditions exist.

Chemical oxidation on the other hand, can be one of three types: atmospheric oxidation, photo-oxidation, or oxidation catalyzed by materials present in the oil. Alkene, alkane and aromatic hydrocarbons with suitable side chains would be attacked most readily. However, the requirements in terms of dissolved oxygen make the process relatively insignificant especially with such low DO measurements.

According to recent research, "oils contained in a natural bottom sediment under aerobic conditions persist longer than do other organics. Under anaerobic conditions in the presence of sulfates, however, the reverse is true, oils being lost more readily than other organics". Assuming that new discharges are abated and that adequate sulfates are present, the hexane-extractables may be expected to fully decompose in approximately 5 years. A decline in the amount of sulfates present and/or aerobic conditions may prolong the decomposition to 13 years or more.

Some parameters which have been correlated with oil decomposition include a high BOD, indicating decomposition of the sludge oil, a slight but steady release with time of organic carbon from the sediment and a slight but persistent drop in pH for the overlying water.

In regard to the oil-soaked bank condition which exists along the Mahoning River, an extensive literature search revealed little pertinent information. The only analagous situation is the effect of oil on land. Several studies have revealed that some microorganisms normally found in the soil will attack petroleum hydrocarbons and utilize them as a source of carbon. This interaction is dependent upon such environmental conditions as temperature, moisture, soil properties, oil content and composition, microbial content, acclimation period, and the availability of oxygen and nutrients. When oil is the only or the predominant source of carbon, oil degrading microorganisms survive and become dominant. The rate of oil decomposition on land was estimated at 0.5 lbs./cu.ft./month through experimentation, which is equivalent with an average accumulated volume of approximately 1.24 lbs./cu.ft. in the study area. Quite obviously, this rate of removal was not under the same conditions as present in the Mahoning River study area, but a fairly rapid rate of removal may be anticipated.

Therefore, if the 70,000 to 110,000 pounds per day of oil and grease now discharged to the river were significantly reduced, it is estimated that the oil in the bottom sediments and bank material could be substantially eliminated within 5 to 10 years, and perhaps sooner.

D. ALTERNATIVE PLANS

The last step in the process of formulating alternatives is the development of alternative plans consisting of the previously discussed compatible measures and/or combinations of measures which were found feasible in the previous two evaluation phases. Each plan will address the solutions to the problems of polluted sludges and oil-soaked banks (albeit to differing degrees) from no action to complete removal of all sludges and oil-soaked bank material.

For any of the alternative plans to provide an enduring solution to the problem of polluted sludges and oil-soaked banks, municipal and industrial point sources as well as urban storm and combined sewer discharges must be controlled. No alternative plan will, in the long term, provide an improvement over the existing condition unless urban point and non-point discharges are significantly improved. Due to the importance of controlling urban discharges, this measure is an integral component of all the following alternative plans with the exception of the "no action" alternative.

Alt. 1 No Action.

Alt. 2 No Action except urban point and non-point discharge control.

This alternative plan would depend entirely upon the natural curative powers of the river to remove the bottom sludges and oil and grease from the banks following the effective control of urban discharges.

Alt. 3 Dredge all sludge from Reaches 3 through 12 and excavate oil-soaked banks in Reaches 5 through 10. Dispose of material having an iron concentration of less than 35% in new landfill sites and recover iron from materials which have an iron concentration exceeding 35%. Remove dams at River Mile 21.1, 13.0 and 6.9. This alternative plan would provide the maximum solution in removing all polluted materials.

Alt. 4 Dredge sludges from Reaches 5 and 10 only. Dispose of material having an iron concentration less than 35% in new landfill sites and recover iron from material containing an iron concentration in excess of 35%. Remove dams at River Mile 21.1, 13.0 and 6.9.

This alternative plan would remove the bottom sludge material which represents the largest single deposit (Reach 5) and the sludge material from the most stressed Reach (Reach 10). It would rely upon the natural curative powers of the river to degrade and eventually eliminate the polluting material from the bank.

Alt. 5 Dredge sludges from Reach 10 only and dispose in a new landfill site. Remove dams at River Mile 6.9, 13.0, and 21.1

This alternative would eliminate the sludges from the most stressed portion of the Mahoning River and would, through the removal of the dams at River Mile 6.9, 13.0 and 21.1, allow a higher degree of reaeration. Again, natural removal of the oil and grease from the banks would occur.

IV. SUMMARY OF ENVIRONMENTAL CONSIDERATIONS

Positive and negative impacts of the various alternative plans are discussed. The intent is not to develop a detailed environmental impact analysis, which would be undertaken if a project develops from this feasibility study, but instead to identify significant direct impacts of each of the alternatives. None of the alternatives would have any impacts on historic properties listed in the National Register of Historic Places or properties eligible for listing in the National Register. In addition, natural areas listed by the Ohio Department of Natural Resources and the Ohio Biological Summary would not be affected by any alternative. There are no known habitat areas for any rare or endangered species of plants or animals which would be affected by any alternative.

ALTERNATIVE 1 - NO ACTION

This alternative would perpetrate existing conditions. The banks would remain oil-soaked and the sediments would remain polluted. Despite these conditions, water quality impacts as a result of these materials are minor relative to the impact of other sources. Water quality standards would not be met without point source controls.

ALTERNATIVE 2 - NO ACTION EXCEPT URBAN DISCHARGE CONTROL

1. Beneficial Impacts

As stated previously, urban discharge control is the single most important action which could be taken to improve the overall quality of the Mahoning River and the quality of the bottom sediments and bank deposits. This alternative plan would depend entirely upon the natural curative powers of the river to improve the quality of the sediments and oil-soaked banks which would, over time, approach the quality found at Leavittsburg. The alternative has the advantage of allowing the quality of the sediments and oil-soaked banks to improve without any disturbance to the river or its banks.

2. Adverse Impacts

There are no adverse environmental impacts associated with this alternative plan.

ALTERNATIVE 3 - DREDGE ALL SLUDGE FROM REACHES 3 THROUGH 12 AND EXCAVATE OIL-SOAKED BANKS IN REACHES 5 THROUGH 10

1. Beneficial Impacts

a. A source of water quality degradation would be removed.

Assuming that urban discharges would be reduced to meet standards, the removal of all polluted materials would substantially eliminate any water quality impact now contributed by the sediment material. The sediments which return to the river would approach the quality found at Leavittsburg.

b. The aesthetics of the river would be improved as far as the oil material in the banks is concerned.

The oil-soaked banks from Republic Steel Corporation (Warren) at River Mile 36.8 to the Lowellville Dam at River Mile 13 are unpleasant to view and difficult to negotiate without either sinking into the material or sliding into the river. The removal of this unsightly material, the stabilization of the banks, and the reseeding of the slopes would improve the appearance and allow better access to the river. However, since the majority of the land is in private ownership, the public benefit derived from this improvement would be limited. In addition, to remove the oil material, many of the trees lining the river would have to be removed to nearly the highwater mark. Tree and other vegetation removal would have a decided negative aesthetic impact.

c. Habitat for aquatic life would be improved.

The removal of sediment and polluted deposits would re-expose natural bottom material, providing an improved environment for benthic organisms. At present, large sections of the river bottom are covered with silt and sludge-type material from both municipal and industrial sources. These deposits and the existing stream water quality prevent the establishment of a diverse population of aquatic organisms. In addition to providing habitat for benthic organisms, the exposed sand, gravel, and rubble would provide spawning areas for a variety of native stream fishes, which could be reestablished.

This improvement of habitat for aquatic life, however, would be dependent upon vastly improved water quality conditions and substantial reduction of upstream silt loads. As long as low head dams are present, sediment would accumulate behind them and cover the native stream bed material. Even with rather stringent water quality standards in effect, the upstream silt load, which at present is difficult to control, would affect the improved habitat in a relatively short time period. Even though a sediment of improved quality would accumulate behind the low head dams, the diversity of benthic organisms would still be low. It is expected that a few additional species of sludge worms, leeches, and midge fly larvae would invade the area, but few, if any, higher quality organisms would be expected to find an acceptable habitat in the sediments. Where the low head dams are removed and a free flowing stream reestablished, sediment will tend not to accumulate, thus permitting the establishment of a diverse population of aquatic organisms.

Reaches 7, 10, and 11 would be expected to have habitat sufficient for higher quality organisms as a result of dam removal.

d. A resource (iron) would be recovered.

Iron might be recovered from the river which otherwise would be lost. As a result, less landfill space would be required and a certain portion of the costs of dredging can be defrayed.

e. Reaeration will be improved by returning several sections of the river to a more natural condition.

The removal of low head dams located at River Mile 21.2, 13.0 and 6.9, would return approximately 5-1/2 miles of the river to a more natural state. Sediments would tend not to accumulate, thus exposing the natural stream bottom and permitting reaeration and providing a habitat of suitable quality for various taxa of aquatic organisms. The river stretch from River Mile 16.3 to the Beaver River would be unobstructed for migration of aquatic organisms and would have a substrate suitable for aquatic life.

2. Adverse Impacts

a. Temporary resuspension of pollutants would occur during dredging and excavation.

The in-stream dredging operation would cause an immediate environmental impact upon the river as in-place deposits are disrupted and suspended. Probable in-stream suspended solids concentrations would rise to 1,000 to 10,000 mg/l and cause a short term violation of most, if not all, of the water quality standards in many of the stream reaches. This violation would be short lived since the suspended solids should settle rapidly downstream; there does exist, however, a potential for oxygen depletion which may create a slug of deoxygenated water prior to the achievement of reaeration over the dams. In terms of heavy metals, even though violations would occur, they probably would not create a toxic condition since they are largely bound with the sediments and have no immediate soluble availability.

b. Temporary and permanent encumbrance of private property would be required for easements and landfill sites.

Approximately 80 acres would be acquired for new Corps landfill sites. This may create a certain degree of hardship to the property owners and the local units of government would loose some tax revenue. In addition, 175 acres would be required for temporary easements. No buildings, however, would require removal.

c. An undetermined number of trees would be removed over a total area of about 145 acres.

Riverine habitat provided by the trees would be affected as a result of the removal of oil-soaked banks material. Since the Mahoning flows through a heavily urbanized area, the wooded areas along the river are somewhat unique. As such, the tree-lined banks provide a corridor of movement for various fauna between otherwise isolated habitat islands. The removal of vegetation from the banks would eliminate the shading which is now provided and would contribute to an elevated water temperature.

d. The exposed stream banks would contribute to additional erosion and sedimentation.

Although the stream banks would be revegetated with native tree species and various grasses following the removal of the oil-soaked material, some erosion would occur. Table 19, taken from the Northeast Ohio Water Development Plan, shows that approximately 56.8% of the sediment load entering the Mahoning River is derived from stream bank erosion. Exposing the stream banks would lead to additional sedimentation until the banks are again revegetated sufficiently to hold the soil.

e. Sediments would reaccumulate to nearly the same quantities from upstream non-point sources within 10 to 16 months.

Based on the information developed in the previous chapter, it was estimated that 95% of the sediments were non-urban derived and that even if the major upstream reservoirs captured 50 to 70 percent of the total sediment load, 350,000 to 625,000 tons of material per year would be available for settling in the river. Based on this information, sludges could reaccumulate to nearly the same quantities as exist now in a relatively short period of time, except in the reaches where dams have been removed. The reaccumulated sediments would be of improved quality approaching those found at Leavittsburg assuming that stringent urban point and non-point source controls are implemented before dredging. If such controls are not implemented, the reaccumulated sediments would approach the same quality which currently exists.

f. Leachate from landfill sites may require treatment before discharge.

Although it is believed that the leachate would be in small enough quantities not to require treatment before discharge, it is possible that treatment might be required. If required, additional annual costs would be incurred over a long time span. In addition, the sludges produced from such treatment would themselves require disposal in landfills.

ALTERNATIVE 4 - DREDGE SLUDGES FROM REACHES 5 AND 10 ONLY

This alternative would provide many of the benefits of Alternative 3 with fewer adverse impacts.

1. Beneficial Impacts

a. A source of water quality degradation would be removed.

The largest single concentration of sludge (Reach 5) and the sludges creating the most severe impact (Reach 10) would be removed with only about 13 linear miles of stream disturbed.

b. Iron would be recovered.

Similar benefits would be realized as discussed in Alternative 2.

c. Habitat for aquatic life would be improved.

Slight improvements in habitat would occur in Reach 5 as a result of dredging. As long as upstream sediments are uncontrolled, no significant habitat improvements would be realized. As a result of dam removal, however, Reaches 7, 10, and 11 should show a significant improvement in habitat supportive of an improved diversity of taxa.

d. Reaeration would be improved by returning several sections of the river to a more natural state.

The same benefits as discussed in Alternative 2 would occur for this Alternative.

e. Oil and grease in the bank materials would be left to degrade naturally without any disturbance of the stream banks.

If oil and grease discharges are greatly reduced or eliminated, the oil and grease now accumulated from River Mile 36.8 to River Mile 13.0 would be expected to degrade and be removed by natural decay and displacement within a relatively short time period (5 to 10 years). The riverine habitat would remain essentially undisturbed which is positive with respect to wildlife and environmentally sound.

2. <u>Adverse Impacts</u>

a. Temporary resuspension of pollutants would occur during dredging.

Similar impacts as discussed in Alternative 3 would occur, although to a lesser extent, because fewer areas would be dredged and the banks would be left undisturbed.

b. Temporary and permanent encumbrance of property would be required for easements and landfill sites.

Approximately 16 acres of private land would be acquired for landfill sites which may create a certain hardship to the affected property owners and would reduce property taxes to local units of government. In addition, approximately 25 acres for temporary easements would be required for access to the river and temporary dewatering basins. No buildings would require removal.

c. Sediments would reaccumulate in Reach 5 to nearly the same mass as exists now within 10 to 16 months, although the sediments would be of better quality if point and non-point sources are better controlled.

The same impact would exist in Reach 5 as a result of upstream sediment loads as was discussed for Alternative 3.

d. Leachate from landfill sites may require treatment before discharge.

Again, similar impacts as discussed for Alternative 3 would occur if leachate requires treatment. There would be fewer landfill sites and therefore fewer treatment facilities required than might be necessary for Alternative 3.

ALTERNATIVE 5 - DREDGE SLUDGES FROM REACH 10 ONLY AND DISPOSE IN A NEW LANDFILL SITE

1. Beneficial Impacts

a. Sediments would be removed from the most stressed river reach.

As shown in the previous Chapter, Reach 10 is the most stressed River Reach. Although more stringent controls on urban discharges would bring about a substantial improvement in the quality of the sediments, the removal of the dam at River Mile 13.0 would still require sludge removal in Reach 10. Dam removal could be accomplished as soon as oil discharges are controlled without significantly impairing downstream water or sediment quality.

b. Habitat for aquatic life would be improved.

The removal of the sludges in Reach 10 would re-expose bottom substrate material for various taxa of aquatic organisms. The removal of the dam at River Mile 13.0 would insure that a substantial portion of the bottom substrate would remain exposed in Reach 10. The elimination of the dams at River Mile 13.0 and 6.9 would remove the barriers for upstream migration of aquatic organisms. Thus, assuming improved waste discharge quality, aquatic life would be able to repopulate the Mahoning River up to River Mile 16.3 from populations of organisms now inhabitating the Shenango River.

c. Reaeration would be improved by returning Reaches 7, 10, and 11 to a more natural state.

The same benefits of dam removal would occur for this alternative plan as were discussed for the previous plans.

d. Oil and grease in the bank materials would degrade naturally without disturbance of the stream banks.

If oil and grease discharges are greatly reduced or eliminated, the oil and grease now accumulated along the river from River Mile 36.8 to River Mile 13.0 are expected to degrade and would be removed by natural decay and displacement within a relatively short time period (5 to 10 years). The riverine habitat could be preserved which is positive aesthetically and environmentally sound over the long term.

2. <u>Adverse Impacts</u>

a. Pollutants would be temporarily resuspended during dredging.

The impact of pollutant resuspension should be minor due to the limited dredging involved. However, some resuspension would occur which potentially could carry both suspended and dissolved materials to the Beaver River in a short time period because no major downstream obstructions exist to trap the suspended sediments.

b. Temporary and permanent encumbrance of private property would be required for easements and a landfill area.

Approximately 1.2 acres of land would be acquired or obtained by easement for a disposal site which may create a certain hardship to the affected property owners. This public acquisition would also remove land from the local tax duplicate. In addition, approximately 5 acres of temporary easements would be required for access to the river and temporary dewatering basins. No buildings would require removal.

c. Leachate treatment may be required before discharge.

Similar impacts as discussed for the other alternatives employing disposal in landfills would occur if leachate requires treatment, but to a much less degree.

V. EVALUATION OF ALTERNATIVE PLANS

In this Chapter, the alternative plans are evaluated and compared with the "no action" alternative.

ALTERNATIVE 1 - NO ACTION

It has been shown in the previous chapters that, although the sludges in Reaches 3 through 12 violate the U.S. EPA criteria for polluted sediments, the impact on water quality is minor. Under worst case conditions, a violation in dissolved oxygen due to sediments acting alone would occur under the Ohio EPA guaranteed winter low flow in Reaches 10 and 11. It was also shown that the average winter flows as measured at the USGS gaging stations are much greater than the Ohio EPA winter low flows. During summer months, the D.O. would be depressed by about 0.5 to 0.8 mg/l as a result of sediments. It has also been shown that during low flow conditions, only iron is soluble enough in the sediments to result in a violation of water quality standards. However, under aerobic conditions, the iron would probably be reprecipitated and fall to the bottom. Under high flow conditions, only three constituents would result in a violation of water quality standards and these metals (copper, lead, and zinc) are highly bound to sediment particles and therefore their toxic impact is low.

ALTERNATIVE 2 - NO ACTION EXCEPT URBAN DISCHARGE CONTROL

The "No Action" alternative assumes no change from present conditions. However, if urban point and non-point discharges were controlled, it was shown that within a period of time, the sediments would approach the quality of those found at Leavittsburg. It was also shown that if oil discharges were significantly reduced, the oil in the banks would be degraded within 5 to 10 years. It should be stated that the quality of the sediments and bank materials are mere reflections of the quality of the discharges to the river. If urban discharges are improved, so the quality of the sediment would be improved. This alternative depends entirely upon the natural curative power of the Mahoning River. This alternative has the advantage of no costs for removal of bank material, but it is entirely dependent upon strict control of urban discharges. Since no low head dams would be removed, there are no reaeration benefits nor are there the benefits to aquatic life associated with a free flowing stream in the lower 16.3 miles of the river.

ALTERNATIVE 3 - REMOVAL OF SLUDGES AND OIL-SOAKED BANKS

This alternative represents the maximum structural approach to solving the problem of polluted sediments. The total costs involved are estimated at $4,497,100 if nearby new landfill sites are acquired and $7,559,900 if a distant private landfill is used. Since it was shown that sediments could re-accumulate to nearly the original quantities within 10 to 16 months after dredging, dredging should not be undertaken until all urban discharges are brought under much better control. Also the benefit of dredging at all is questionable, since such a rapid re-accumulation would occur. Although the new sediment quality would approach the quality of the sediments at Leavittsburg if urban discharge controls were effective, only minor improvement would be apparent either in terms of water quality, aquatic life, or aesthetics. In fact, should most trees along the river require removal, a negative impact would be exerted in terms of terrestrial wildlife and aesthetics.

ALTERNATIVE 4 - REMOVE SLUDGES IN REACHES 5 AND 10 ONLY

This alternative has an advantage over Alternative 3 in that the majority of the sludges would be removed (about 80%), including those creating the most significant dissolved oxygen impact (in Reach 10), at a cost of about one-third that of Alternative 3. Since the banks would not be disturbed, the tree-lined riverine habitat would remain. However, sediments would again accumulate behind the dam at River Mile 27.0 in 10 to 16 months. If urban pollutants are controlled prior to dredging, then the new sediments would approach the quality of those at Leavittsburg. However, no major improvement would be expected in terms of aquatic life entering the area, because as long as significant quantities of sediment are present, regardless of the quality, a low diversity of organisms would occur in the area.

However, assuming urban pollutant control, the removal of the dams at River Mile 13.0 and 6.9 would provide a relatively sediment free river bottom for higher quality aquatic life in 16.3 miles of the river contiguous with the Shenango River. The Shenango River populations of aquatic organisms could easily repopulate the lower 16 miles of the Mahoning River.

The total cost of this alternative is estimated at $1,537,000 if the nearby new landfill sites are employed and $2,537,000 if the distant private site is used.

ALTERNATIVE 5 - DREDGE SLUDGES FROM REACH 10 ONLY

This alternative only removes the sludges from the river reach which suffers the most severe impact as a result of highly polluted sediments in combination with elevated river temperatures. With the removal of the dams at River Mile 13.0 and 6.9, 16.3 miles of river contiguous with the Shenango River could be made suitable for high quality aquatic life, assuming the control of urban discharges. In addition, the removal of the dams would provide a greater degree of reaeration in the Mahoning thereby assisting in the self-purification process before the river joins the Shenango. With the removal of the dams, no substantial re-accumulation of sludges would occur.

Although the above mentioned statements apply to both Alternative 3 and Alternative 4, Alternative 5 accomplishes these benefits at substantially lower total project costs. Both Alternative 3 and 4 remove more total sludges; but as was shown, these have relatively minor impacts on water quality.

The sludges removed in Reach 5 (Alternative 4) and Reaches 3, 4, 5, 6, 8 and 9 (Alternative 3) would re-accumulate in a relatively short period of time. If substantial improvement is made in urban discharge control, the new sediments would be of a higher quality material. However, based on the previously discussed resuspension capacity of the River, substantial replacement of the sludges is predicted to occur naturally.

The cost of Alternative 5 is estimated at $159,000 if a nearby new landfill site is used and $242,000 if the distant private site is used, which amounts to about 3% of the cost of Alternative 3.

In accordance with the Water Resource Council Principles and Standards, a matrix displaying the System of Accounts is presented in Table 28 employing as many accounts as are applicable. Each account is addressed qualitatively and where possible, quantitatively. The No Action Alternative is not displayed since it represents no change from existing conditions.

TABLE 28

ACCOUNTS DISPLAY
(Sheet 1/6)

Description	Alternative 1 No Action	Alternative 2 No Action Except Urban Discharge Control	Alternative 3 Remove all Sludge and Oil-Soaked Bank Material	Alternative 4 Remove Sludge in Reach 5 and 10	Alternative 5 Remove Sludge in Reach 10
I. Natural Economic Development					
Total Costs					
Existing Private Landfill	0	0	7,559,000	2,537,000	242,000
New Publicly-owned Landfill			4,497,000	1,537,000	159,000
II. Environmental Quality					
a. Enhanced					
1. Water Quality	no change	least positive of alternatives except alternative 1	most positive with exception of erosion from banks	positive	less positive than alternative 4
2. Aquatic Life	no change	least positive of alternatives except alternative 1	slightly positive	positive	positive
3. Terrestrial Life	no change	---	---	---	---
4. Land Resources	no change	---	---	---	---
5. Mineral Resources	no change	---	most iron recovered	iron recovered	---

TABLE 28

ACCOUNTS DISPLAY (CONT'D.)
(Sheet 2/6)

Description	Alternative 1 No Action	Alternative 2 No Action Except Urban Discharge Control	Alternative 3 Remove all Sludge and Oil-Soaked Bank Material	Alternative 4 Remove Sludge in Remove 5 and 10	Alternative 5 Remove Sludge in Reach 10
6. Aesthetics	no change	positive improvement of banks over a period of time	oil-soaked bank material removed immediately	positive improvement of banks over a period of time	positive improvement of banks over a period of time
b. Degraded					
1. Water Quality	no change	---	temporary pollutant resuspension enhanced bank erosion	slightly less temporary pollutant resuspension than alternative 3	minor temporary pollutant resuspension
2. Aquatic Life	no change	---	slight degradation as a result of bank erosion	---	---
3. Terrestrial Life	no change	---	145 acres of riverine habitat impacted. 77 acres of scrubland habitat eliminated	16 acres of scrubland habitat eliminated	1.2 acres of scrubland habitat eliminated

TABLE 28

ACCOUNTS DISPLAY (CONT'D.)
(Sheet 3/6)

Description	Alternative 1 No Action	Alternative 2 No Action Except Urban Discharge Control	Alternative 3 Remove all Sludge and Oil-Soaked Bank Material	Alternative 4 Remove Sludge in Reach 5 and 10	Alternative 5 Remove Sludge in Reach 10
4. Land Resources	no change	---	conversion of 77 acres to landfill 145 acres of woodland removed (banks)	conversion of 16 acres to landfill	conversion of 1.2 acres to landfill
5. Mineral Resources	no change	---	---	---	---
6. Aesthetics	no change	---	river banks degraded by removal of vegetation	---	---
III. Social Well Being a. Beneficial					
1. Water Supply	no change	positive improvement	slightly more positive than alternative 2	slightly less positive than alternative 3	slightly less positive than alternative 4
2. Recreation	no change	tree-lined clean stream banks over long term	immediate improvement by removal of oil-soaked bank material	tree-lined clean stream banks over long term	tree-lined clean stream banks over long term

TABLE 28

ACCOUNTS DISPLAY (CONT'D.)
(Sheet 4/6)

Description	Alternative 1 No Action	Alternative 2 No Action Except Urban Discharge Control	Alternative 3 Remove all Sludge and Oil-Soaked Bank Material	Alternative 4 Remove Sludge in Reach 5 and 10	Alternative 5 Remove Sludge in Reach 10
b. Adverse					
1. Water Supply	no change	---	potential significant temporary impact during dredging	slightly less significant than alternative 3	temporary impact during dredging
2. Recreation	no change	---	tree removal on stream banks	---	---
3. Encumbrance of Private Property	no change	---	77 acres acquired 175 acres of easements	16 acres acquired 25 acres of easements	1.2 acres acquired 5 acres of easements
IV. Regional Development					
a. Beneficial	no change	---	temporary employment	temporary employment	minor temporary employment
b. Adverse	no change	---	most property tax loss to local government	some property tax loss to local government	minor property tax loss to local government

TABLE 28

ACCOUNTS DISPLAY (CONT'D.)
(Sheet 5/6)

Description	Alternative 1 No Action	Alternative 2 No Action Except Urban Discharge Control	Alternative 3 Remove all Sludge and Oil-Soaked Bank Material	Alternative 4 Remove Sludge in Reach 5 and 10	Alternative 5 Remove Sludge in Reach 10
V. Specified Evaluation Criteria					
a. Completeness (Ranking 1-5, most to least)	5	4	1	2	3
b. Effectiveness (Ranking 1-5, most to least)	5	4	1	2	3
c. Efficiency (Ranking 1-5, most to least)	1	2	5	4	3
d. Certainty	---	level of urban discharge control uncertain	level of urban discharge control uncertain	level of urban discharge control uncertain	less dependent upon urban discharge control
e. Reversibility (Ranking 1-5, most to least)	1	2	5	4	3

TABLE 28

ACCOUNTS DISPLAY (CONT'D.)
(Sheet 6/6)

Description	Alternative 1 No Action	Alternative 2 No Action Except Urban Discharge Control	Alternative 3 Remove all Sludge and Oil-Soaked Bank Material	Alternative 4 Remove Sludge in Reach 5 and 10	Alternative 5 Remove Sludge in Reach 10
f. Stability (Ranking 1-5, most to least under a variety of alternative futures)	1	2	5	4	3

VI. CONCLUSIONS

1. The accumulated sediments and oil-soaked banks of the Mahoning River have an adverse effect on water quality. However, the sediments have a relatively small effect as compared with industrial and urban point and non-point source discharges.

2. For major improvement of Mahoning River water quality, reliance must be placed upon control of pollution from the industrial and urban sources. Assuming that such control is instituted, removal of the sediments and oil-soaked bank material would have a beneficial impact on the dissolved oxygen of the river, and in meeting the standards for iron, copper, lead and zinc.

3. Natural decay processes and natural sediment transport in the river will result in gradual improvement of sediment deposits, and reduction of their impact on water quality if urban discharges are controlled. It is estimated that within 5 to 10 years, the impact of the sediments would be reduced to the point where no water quality violations would be expected due to the sediments, assuming effective urban source control. The above statements describe the consequences of taking no action to remove sediments or oil-soaked banks, but placing stringent controls on both point and non-point source urban discharges.

4. It was found that removal of three dams along the river, which no longer serve a useful purpose, would improve the dissolved oxygen and temperature conditions in the pools, and prevent some of the accumulation of sediments.

5. Removal of oil-soaked banks would have only a minor beneficial impact on water quality; the benefit of this procedure is mainly aesthetic, and is at least partially offset by the necessity of tree removal and disruption of wildlife habitat.

6. Of the alternatives studied, Alternative 3 would provide the greatest improvement, since all sediment deposits in 10 reaches would be removed, as well as oil-soaked bank materials. Alternative 4 would result in removal of about 80% of the sediment deposits at about one-third the cost of Alternative 3, but without removal of bank material. Alternative 5 would provide improvement by removal of sediments affecting Reach 10, which is the reach most severely

affected by sediment-induced D.O. depression under critical winter low flow conditions. These sediments also contain a higher concentration of specific pollutants than most other sediment deposits. The cost of Alternative 5 is only about 3% of Alternative 3. Alternatives 3, 4, and 5 all include removal of three unused low-head dams.

7. Alternative 2, would show no immediate improvement in sediment quality, but gradual reduction of sediment impact on water quality would result from natural decay and sediment displacement processes, if urban and industrial pollution discharges are controlled.

8. Alternative 5 appears to provide the greatest degree of improvement per dollar expended and would have some benefit even in the absence of control of urban and industrial discharges.

   Since the additional incremental costs of Alternative 3 and 4 over the costs of Alternative 5 produce an incremental improvement <u>only</u> if control of polluting discharges are effective, adoption of Alternatives 3 and 4 without concurrent substantial urban discharge control involve a risk that these incremental costs could be wasted.

VII. RECOMMENDATIONS

Based upon the conclusions of this study, it is recommended that:

1. Alternative 5 be adopted and implemented. This alternative has a total cost of $159,000 and includes the following items:

   a. Removal of the low head dams located at River Mile 21.1, 13.0, and 6.9. The removal of these unused dams would reduce sediment accumulation in the pools created by them and would increase the reaeration capacity of the river.

   b. Removal of the sludge deposits in Reach 10. This reach contains some of the most polluted sediments in the river. The removal of the dam at River Mile 13.0 would allow these sludges to move downstream if they were not removed.

   c. Improved control of urban point and nonpoint source discharges.

2. Sludge be removed from Reach 10 and the three low head dams be removed without waiting for substantial improvement of the quality of urban discharges. Some improvement of the water quality of the Mahoning River could be achieved without the control of urban point and nonpoint discharges, although maximum benefit would not occur until these pollution sources are better controlled.

3. The sediments be re-examined as progressive improvements are made in the quality of urban discharges to monitor the response of the sediments to improved quality. Should significant improvements in the quality of the sediments not occur as predicated with higher quality urban discharges, additional corrective measures can be implemented.

APPENDIX A

WATER QUALITY TABLES

TABLE A-1
(Sheet 1/5)

WATER QUALITY STANDARDS

Parameter	Ohio Warm Water Fisheries	Ohio - Mahoning River - 1972 Standards: Warren to Lowellville Dam	Ohio - Mahoning River - 1972 Standards: Lowellville Dam to Ohio-Penn State Line	Ohio Mahoning River Proposed Standard, Ind. Water Supply and Assimilation of Waste Water Discharges: Main St. (1) Bridge Warren to State Line	Ohio Mahoning River Proposed Standard, Ind. Water Supply and Assimilation of Waste Water Discharges: Ohio-Penn State Line	Penn. Mahoning River Standards
Dissolved Oxygen						
Daily Avg. (mg/1)	5	5	5	3(2)	5	5
Minimum (mg/1)	4	4	4	1	4	4
Total Coliform-No/100 ml						
Monthly Average and 80% of samples less than			5,000			
Maximum - 95% less than			20,000			
Fecal Colifrom-No/100 ml						
Geometric Mean	200	1,000	200			200
Maximum - 90% less than	400	2,000	400			
pH-Units						
Maximum	9	8.5	8.5	9.0	9.0	8.5
Minimum	6.0	6.0	6.0	6.0	6.0	6.0
Threshold Odor No.	24 at 40°C		24 at 60°C		24 at 60°C	24 at 60°C
Dissolved Solids						
Monthly Avg. (mg/1)		500	500			500
Maximum (mg/1)		750	750			750
May exceed one but not both	1,500 or 150 due to human activities					

(1) Leavittsburg Dam to Main Street within the City of Warren shall meet Ohio Warm Water Fisheries Standards by January 1, 1979. Prior to this date this reach will meet standards applied to the remainder of the lower Mahoning River.

(2) Downstream of Lowellville Dam, Dissolved Oxygen will not be less than 5.0 mg/1 as a daily avg. nor less than 4.0 mg/1 at any time.

TABLE A-1
(Sheet 2/5)

WATER QUALITY STANDARDS - (CONT'D.)

Parameter	Ohio Warm Water Fisheries	Ohio - Mahoning River - 1972 Standards: Warren to Lowellville Dam	Ohio - Mahoning River - 1972 Standards: Lowellville Dam to Ohio-Penn State Line	Ohio Mahoning River Proposed Standard, Ind. Water Supply and Assimilation of Waste Water Discharges: Main St.(1) Bridge Warren to State Line	Ohio Mahoning River Proposed Standard, Ind. Water Supply and Assimilation of Waste Water Discharges: Ohio-Penn State Line	Penn. Mahoning River Standards
Temperature	Not to exceed the following: Jan,Feb-50°F(10.0°C) March-60°F(15.6°C) April,Nov-70°F(21.1°C) May-80°F(26.7°C) June,July, Aug,Sept-90°F(32.2°C) Oct-78°F(25.6°C) Dec-57°F(13.9°C)	Not to exceed temperature measured at Leavittsburg monitor by more than the following: 5°F-April to Nov. 10°F-Dec. to Nov.	Same as Ohio Warm Water	*	Summer 92°F Winter 83°F	Same as Ohio Warm Water
Toxicity	1/10 of the 96 hour TLM	1/10 of the 96 hour TLM	1/10 of the 96 hr. TLM			Water shall not contain substances attributable in sufficient amounts to be harmful to human, animal, plant or aquatic life
Radioactivity-picouries/1						
Gross Beta Activity	100		1,000			
Strontium 90	10		10			
Alpha Emitters	3		3			

*See Sheet 5/5.

TABLE A-1
(Sheet 3/5)

WATER QUALITY STANDARDS - (CONT'D.)

Parameter	Ohio Warm Water Fisheries	Ohio - Mahoning River - 1972 Standards: Warren to Lowellville Dam	Ohio - Mahoning River - 1972 Standards: Lowellville Dam to Ohio-Penn State Line	Ohio Mahoning River Proposed Standard, Ind. Water Supply and Assimilation of Waste Water Discharges: Main St.(1) Bridge Warren to State Line	Ohio Mahoning River Proposed Standard, Ind. Water Supply and Assimilation of Waste Water Discharges: Ohio-Penn State Line	Penn. Mahoning River Standards
Freedoms	Free from substances associated with human activities which result in sludge deposits, floating materials, color, turbidity or any other nuisance conditions	Same as Ohio Warm Water	Same as Ohio Warm Water			Substances to be controlled shall include but not limited to, floating debris, oil, scum, and other floating materials, toxic substances and substances which produce color, tastes, odors, or settle to form sludges.
Chemical Constituents - mg/l Total unless otherwise indicated						
Ammonia N	1.5			*	*	
Arsenic	0.05		0.05			
Barium	0.8		1.0			
Cadmium	0.005		0.005			
Chloride	250				250	
Chromium	0.3					
Chromium(hexavalent)	0.05		0.05			
Cyanide	0.2		0.025	*	*	0.025
Cyanide(free)	0.005					
Fluoride	1.3		1.0		1.0	1.0
Foaming Agents(MBAS)	0.5					
Iron						
Total						1.5
Dissolved	1.0				0.3	

*See Sheet 5/5.

TABLE A-1
(Sheet 4/5)

WATER QUALITY STANDARDS - (CONT'D.)

Parameter	Ohio Warm Water Fisheries	Ohio - Mahoning River - 1972 Standards: Warren to Lowellville Dam	Ohio - Mahoning River - 1972 Standards: Lowellville Dam to Ohio-Penn State Line	Ohio Mahoning River Proposed Standard, Ind. Water Supply and Assimilation of Waste Water Discharges: Main St.(1) Bridge Warren to State Line	Ohio Mahoning River Proposed Standard, Ind. Water Supply and Assimilation of Waste Water Discharges: Ohio-Penn State Line	Penn. Mahoning River Standards
Lead	0.04		0.05		1.0	
Manganese						
Manganese (dissolved)	1.0					
Mercury	0.0005		0.005			
Oil & Grease (Hexane soluble)	5.0					
Phenols	0.01			*	0.005	0.005
Selenium	0.005		0.005			
Silver	0.001		0.05			
Copper and Zinc (Hardness as $CaCO_3$)	Hardness / Cu / Zn					
	0-80 / 0.005 / 0.075					
	80-160 / 0.01 / 0.1					
	160-240 / 0.02 / 0.2					
	240-320 / 0.05 / 0.4					
	>320 / 0.075 / 0.5					
Sulfates					250	

See Sheet 5/5.

TABLE A-1
(Sheet 5/5)
WATER QUALITY STANDARDS - (CONT'D.)
(Ohio Water Quality Standards)

Constituent	Leavittsburg Dam Main St. (Warren)	Main St. to Mosquito Cr.	Mosquito Cr. to Mill Cr.	Mill Cr. to Yellow Cr.	Ohio - Pa. State Line
Water Temp. °F					
Summer	78.5°F	86°F	93°F	95°F	92°F
Winter	40.0°F	58°F	68°F	93°F	83°F
Ammonia - N - mg/l					
Summer	0.3	0.85	0.70	1.20	0.95
Winter	0.3	1.15	0.90	1.85	1.35
Cyanides - Total mg/l					
Summer	0.020	0.036	0.036	0.060	0.025
Winter	0.020	0.075	0.075	0.100	0.034
Phenols - mg/l					
Summer	0.0025	0.012	0.010	0.012	0.005
Winter	0.005	0.024	0.020	0.020	0.005

TABLE A-2

WATER QUALITY DATA - mg/1 and noted
11, 12, 13 14 February 1975
(Sheet 1/9)

Identification	Mahoning River Leavittsburg	Copper-Weld		Republic Steel Warren No. 1		Republic Steel Warren No. 2	
		I	O	I	O	I	O
River Mile	46.2	42.5		37.7		36.7	
Flow, mgd	-	34.6		6.1		12.0	
cfs	840	53.5		9.5		18.6	
Parameter							
Temp., °C	2.2	2.0	5.2	1.9	16.8	1.6	17.6
DO	14.3	13.9	12.6	14.0	-	13.8	-
COD	10	14	19	17	95	18	189
BOD_5	<3	<2	<5	<2	44	<2	11
BOD_{20}	8	8	10	8	34	8	42
TKN	0.5	0.7	0.6	0.5	1.0	0.5	6.0
NH_3-N	0.2	0.3	0.4	0.3	0.9	0.3	4.4
NO_3+NO_2-N	0.9	1.4	0.8	0.9	0.7	0.9	1.0
PO_4-P, total	0.10	0.16	0.12	0.18	0.37	0.18	0.52
Cyanide, total	0.006	0.004	0.003	0.022	-	0.022	0.27
Phenol	0.017	0.003	0.003	0.005	-	0.005	0.62
SS	7	9	19	12	35	12	376
TDS	270	260	267	257	485	257	338
Chloride	24	26	28	29	153	29	44
Fluoride	0.2	0.2	0.2	0.2	13	0.2	0.8
Hardness as $CaCO_3$	140	-	-	-	-	-	-
Sodium	16	17	20	18	35	18	25
Sulfate	72	76	77	79	103	79	87
Cadmium	<0.008	<0.008	<0.008	<0.008	0.034	<0.008	0.006
Chromium	0.022	<0.02	0.017	0.007	0.099	0.007	0.080
Copper	0.032	0.077	0.086	0.047	0.106	0.047	0.234
Iron	0.5	0.8	2.8	1.4	38	1.43	152
Lead	<0.05	<0.05	0.17	<0.05	0.051	<0.05	0.52
Zinc	<0.03	-	-	0.14	3.6	0.14	0.73

I - Intake
O - Outfall

Source of data: U.S. Environmental Protection Agency, 1975

TABLE A-2 - (CONT'D.)

WATER QUALITY DATA - mg/1 and noted
11 12, 13, 14 February 1975
(Sheet 2/9)

Identification	Warren WWTP	Mahoning River West Park Ave.	At Mouth of Mosquito Creek	At Mouth of Meander Creek
River Mile	35.8	33.8	31.3	30.9
Flow, mgd	12.2	-	-	-
cfs	18.9	860+	+	+
Parameter				
Temp., °C	11.0	3.4	2.0	3.0
DO	8.7	13.4	13.3	11.0
COD	201	20	21	16
BOD_5	74	4.5	2	<2
BOD_{20}	112	12	11	16
TKN	18.7	1.3	1.0	1.8
NH_3-N	10.2	0.8	0.6	1.4
NO_3+NO_2-N	1.0	0.7	0.7	1.1
PO_4-P, total	4.9	0.50	0.17	0.73
Cyanide, total	0.223	0.023	0.011	0.021
Phenol	0.09	0.048	0.015	0.003
SS	71	15	12	16
TDS	709	280	237	373
Chloride	162	35	37	41
Fluoride	1.0	0.44	0.31	0.82
Hardness as $CaCO_3$	-	151	145	182
Sodium	124	23	22	42
Sulfate	171	78	67	132
Cadmium	<0.01	<0.008	<0.008	<0.008
Chromium	0.30	0.19	0.03	<0.02
Copper	0.05	0.45	0.02	0.037
Iron	1.3	7.90	3.1	2.5
Lead	<0.05	<0.05	<0.05	<0.05
Zinc	0.24	0.16	0.19	0.06

Source of data: U.S. Environmental Protection Agency, 1975.

TABLE A-2 - (CONT'D.)

WATER QUALITY DATA - mg/l and noted
11, 12, 13, 14 February 1975
(Sheet 3/9)

Identification	Mahoning River Ohio Edison	Niles WWTP	U.S. Steel McDonald Works I	U.S. Steel McDonald Works O	McDonald WWTP
River Mile	30.2	29.5	28.6		27.6
Flow, mgd	-	4.3	46.3		0.5
cfs	860+	6.6	71.6		0.8
Parameter					
Temp., °C	2.7	10.1	4.9	8.4	-
DO	13.2	5.9	12.7	12.2	7.0
COD	23	153	29	27	117
BOD_5	6	75	4	<5	44
BOD_{20}	16	134	16	47	107
TKN	1.4	18.4	2.7	1.4	19.7
NH_3-N	0.8	10.7	0.9	0.8	11.7
NO_3+NO_2-N	0.8	0.7	0.9	1.0	0.9
PO_4-P, total	0.26	6.5	0.25	0.20	6.5
Cyanide, total	0.026	0.021	0.029	-	0.013
Phenol	0.047	0.027	0.032	-	0.019
SS	15	34	1	32	21
TDS	297	591	287	290	561
Chloride	38	92	38	38	89
Fluoride	0.42	0.63	0.45	0.45	0.71
Hardness as $CaCO_3$	153	-	-	-	-
Sodium	23	80	22	23	71
Sulfate	78	176	81	68	156
Cadmium	<0.008	0.008	<0.008	<0.008	<0.008
Chromium	0.028	0.023	0.015	0.027	<0.02
Copper	0.063	0.04	0.013	0.030	0.017
Iron	3.0	2.4	2.6	9.0	0.45
Lead	<0.05	0.06	<0.05	<0.05	<0.05
Zinc	0.19	-	-	0.18	0.10

I - Intake
O - Outfall

Source of data: U.S. Environmental Protection Agency, 1975.

TABLE A-2 - (CONT'D.)

WATER QUALITY DATA - mg/l and noted
11, 12, 13, 14 February 1975
(Sheet 4/9)

Identification	Girard WWTP	Youngstown Sheet and Tube Brier Hill I	Youngstown Sheet and Tube Brier Hill O	U.S. Steel Ohio Works I	U.S. Steel Ohio Works O	Mahoning River Bridge St.
River Mile	25.7	23.4		23.2		22.9
Flow, mgd	2.2	25.5		26.2		-
cfs	3.4	39.4		40.5		1,060
Parameter						
Temp., °C	11.2	5.6	14.1	3.4	13.8	4.6
DO	6.8	-	-	-	-	11.7
COD	180	22	44	27	29	26
BOD_5	74	4	4	<5	<3	6.0
BOD_{20}	162	20	40	15	41	24
TKN	20.2	1.6	3.4	1.6	3.1	1.6
NH_3-N	11.5	1.1	2.6	1.0	2.3	1.1
NO_3+NO_2-N	0.6	0.8	0.9	0.9	0.9	0.9
PO_4-P, total	5.4	0.22	0.34	0.27	0.35	0.27
Cyanide, total	0.024	0.058	0.401	0.032	-	0.074
Phenol	0.032	0.032	0.177	0.037	0.019	0.064
SS	40	18	56	14	25	17
TDS	609	297	338	283	331	300
Chloride	108	42	62	39	147	44
Fluoride	0.81	0.40	0.45	0.44	0.98	0.46
Hardness as $CaCO_3$	-	-	-	-	-	162
Sodium	97	25	38	26	31	28
Sulfate	149	88	89	83	82	82
Cadmium	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
Chromium	<0.024	0.025	0.027	0.02	0.023	0.023
Copper	0.046	0.013	0.025	0.021	0.014	0.040
Iron	0.58	3.7	9.7	2.47	3.94	3.33
Lead	<0.05	<0.05	<0.05	<0.05	<0.10	0.050
Zinc	0.23	0.17	0.23	-	-	0.21

I - Intake
O - Outfall

Source of data: U.S. Environmental Protection Agency, 1975.

TABLE A-2 - (CONT'D.)

WATER QUALITY DATA - mg/l and noted
11, 12, 13, 14 February 1975
(Sheet 5/9)

Identi-fication	Mouth of Mill Creek	Mahoning River Marshall Ave.	Mouth of Crab Creek	Youngstown WWTP
River Mile	22.2	21.0	19.9	19.8
Flow, mgd	-	-	-	22.7
cfs	+	1,060+	+	35.1
Parameter				
Temp., °C	0.3	5.0	2.4	11.1
DO	13.4	11.8	11.9	8.9
COD	12	23	19	157
BOD_5	3.5	5.5	4.7	54
BOD_{20}	10	23	16	86
TKN	0.4	1.9	0.8	14.6
NH_3-N	0.2	1.2	0.5	7.9
NO_3+NO_2-N	1.2	0.9	1.2	2.1
PO_4-P, total	0.22	0.32	1.7	5.8
Cyanide, total	0.009	0.109	0.015	0.462
Phenol	0.003	0.046	0.330	0.046
SS	4	14	8	42
TDS	510	293	520	945
Chloride	114	47	162	314
Fluoride	0.35	0.44	0.32	1.1
Hardness as $CaCO_3$	231	160	232	-
Sodium	72	121	91	218
Sulfate	125	84	105	154
Cadmium	<0.008	<0.008	<0.008	<0.008
Chromium	<0.03	<0.025	0.08	0.033
Copper	0.025	0.043	0.01	0.057
Iron	0.36	2.4	0.79	1.1
Lead	<0.05	<0.05	0.06	0.073
Zinc	0.04	0.25	0.16	0.31

Source of data: U.S. Environmental Protection Agency, 1975.

TABLE A-2 - (CONT'D.)

WATER QUALITY DATA - mg/l and noted
11, 12, 13, 14 February 1975
(Sheet 6/9)

Identification	Mahoning River B&O RR	Republic Steel I	Republic Steel O	Mouth of Dry Run	Republic Steel I	Republic Steel O
River Mile	19.3	18.7		18.7	18.4	
Flow, mgd	-	7.9		-	8.2	
cfs	1090+	12.2		+	12.7	
Parameter						
Temp., °C	5.2	3.7	24.3	5.3	3.7	10.6
DO	11.4	-	-	6.1	-	-
COD	25	31	42	125	31	82
BOD_5	8.3	5.3	9	34	5.3	23
BOD_{20}	25	24	69	65	24	57
TKN	2.3	2.5	12.7	9.9	2.5	7.6
NH_3-N	1.5	1.4	10.4	3.5	1.4	6.1
NO_3+NO_2-N	1.4	1.0	1.1	1.8	1.0	1.2
PO_4-P, total	0.52	0.49	0.85	3.1	0.49	0.58
Cyanide, total	0.13	0.19	1.1	0.018	0.19	1.65
Phenol	0.06	0.045	2.0	0.013	0.045	4.1
SS	17	16	61	60	16	27
TDS	320	333	344	1,423	333	365
Chloride	57	59	82	311	59	62
Fluoride	0.50	0.49	1.18	0.50	0.49	0.49
Hardness as $CaCO_3$	166	-	-	263	-	-
Sodium	37	38	32	208	38	38
Sulfate	88	92	70	418	93	101
Cadmium	0.008	0.034	0.047	<0.008	0.034	0.106
Chromium	0.03	0.017	0.02	0.095	0.017	0.031
Copper	0.04	0.038	0.12	0.063	0.038	0.048
Iron	2.2	5.2	45.3	85	5.2	5.4
Lead	0.05	<0.05	0.21	<0.06	0.05	0.32
Zinc	0.22	-	-	0.138	-	-

I - Intake
O - Outfall

Source of data: U.S. Environmental Protection Agency, 1975.

TABLE A-2 - (CONT'D.)

WATER QUALITY DATA - mg/l and noted
11, 12, 13, 14 February 1975
(Sheet 7/9)

Identification	Mahoning River Conrail	Youngstown Sheet and Tube Campbell Works I	Youngstown Sheet and Tube Campbell Works O	Campbell WWTP	Mahoning River RL&E RR
River Mile	18.0	16.5		16.2	16.0
Flow, mgd	-	17.9		2.6	-
cfs	1,090+	27.8		4.0	1,100+
Parameter					
Temp., °C	6.6	7.5	15.6	8.9	7.4
DO	11.1	-	-	10	11.0
COD	30	24	51	102	33
BOD_5	16	5.7	5.5	49	12
BOD_{20}	30	27	62	106	30
TKN	3.0	2.6	4.4	13.4	3.0
NH_3-N	2.1	1.8	3.4	5.9	2.2
NO_3+NO_2-N	1.9	0.9	1.0	1.6	0.9
PO_4-P, total	0.6	0.59	0.57	4.5	0.82
Cyanide, total	0.20	0.149	0.723	0.046	0.23
Phenol	0.12	-	0.453	0.022	0.15
SS	18	21	51	18	25
TDS	350	337	372	744	397
Chloride	63	58	67	143	68
Fluoride	0.52	0.45	0.66	0.45	0.55
Hardness as $CaCO_3$	173	-	-	-	185
Sodium	41	34	37	95	40
Sulfate	91	93	104	256	98
Cadmium	<0.008	<0.008	<0.008	<0.008	<0.008
Chromium	0.03	0.063	0.186	<0.02	0.047
Copper	0.043	0.028	0.037	0.044	0.057
Iron	3.2	4.9	12.2	0.48	4.6
Lead	<0.05	0.17	0.088	<0.05	<0.05
Zinc	0.74	0.28	0.70	0.98	0.33

I - Intake
O - Outfall

Source of data: U.S. Environmental Protection Agency, 1975.

TABLE A-2 - (CONT'D.)

WATER QUALITY DATA - mg/l and noted
11, 12, 13, 14 February 1975
(Sheet 8/9)

Identification	Mouth of Yellow Creek	Struthers WWTP	Mahoning River Washington St.	Lowellville WWTP
River Mile	15.8	15.0	12.9	12.6
Flow, mgd	-	3.8	-	0.5
cfs	+	5.8	1,280+	0.8
Parameter				
Temp., °C	0.6	8.4	6.7	11.3
DO	14.1	9.1	10.8	10.9
COD	16	108	37	75
BOD_5	2.3	46	11	40
BOD_{20}	9	113	37	66
TKN	0.4	14.6	3.3	11.8
NH_3-N	0.1	7.8	2.4	3.4
NO_3+NO_2-N	1.9	1.0	1.0	1.6
PO_4-P, total	0.15	4.3	0.62	5.7
Cyanide, total	0.005	0.029	0.20	0.035
Phenol	0.002	0.02	0.14	0.014
SS	13	22	23	38
TDS	587	700	357	590
Chloride	35	111	65	88
Fluoride	0.24	0.48	0.54	0.39
Hardness as $CaCO_3$	357	-	187	-
Sodium	27	133	42	105
Sulfate	245	230	94	194
Cadmium	<0.008	<0.008	<0.008	<0.008
Chromium	0.017	<0.02	0.035	<0.02
Copper	0.33	0.023	0.035	0.076
Iron	0.46	0.68	3.1	0.45
Lead	<0.05	<0.05	0.05	0.085
Zinc	0.018	0.10	0.33	-

Source of data: U.S. Environmental Protection Agency, 1975.

TABLE A-2 - (CONT'D.)

WATER QUALITY DATA - mg/l and noted
11, 12, 13, 14 February 1975
(Sheet 9/9)

Identification	MAHONING RIVER Churchill Road	Rt. 224	Brewster Rd.	Conrail
River Mile	9.9	7.0	4.6	1.8
Flow, mgd	-	-	-	-
cfs	1,280+	1,280+	1,280+	1,280+
Parameter				
Temp., °C	6.9	6.5	6.6	6.3
DO	10.5	10.3	10.2	9.7
COD		34		32
BOD_5		7.6		9.7
BOD_{20}		33		35
TKN		3.1		3.1
NH_3-N		2.2		2.2
NO_3+NO_2-N		1.0		1.0
PO_4-P, total		0.51		0.40
Cyanide, total		0.17		0.16
Phenol		0.08		0.07
SS		17		20
TDS		393		343
Chloride		63		63
Fluoride		0.48		0.48
Hardness as $CaCO_3$		184		188
Sodium		41		42
Sulfate		100		101
Cadmium		<0.008		<0.008
Chromium		0.045		0.053
Copper		0.055		0.03
Iron		3.5		4.0
Lead		0.05		0.05
Zinc		0.33		0.35

Source of data: U.S. Environmental Protection Agency, 1975.

APPENDIX B

TRACTIVE FORCE METHOD FOR THE DETERMINATION OF STABLE STREAM CROSS SECTIONS

APPENDIX B

TRACTIVE FORCE METHOD FOR THE DETERMINATION OF STABLE STREAM CROSS SECTIONS

I. DEFINITIONS

Y_o = Depth at mid-section (feet)

τ_o = Tractive force (lbs./SF), taken as 0.1

W = Density of water (lbs./CF)

S = Slope of water surface (ft./ft.)

Y = Depth at any point (feet)

Θ = Angle of repose (degrees), taken as 25°

X = Laterial dimension to Y as measured from Y_o (feet)

T = Stream width (feet)

V = Velocity (fps)

n = Manning's constant, taken as 0.035

A = Cross sectional area (SF)

Q = Theoretical discharge (cfs)

Q' = Design discharge when $Q' < Q$ (cfs)

T' = Width increment to be subtracted

Q" = Design discharge when $Q'' > Q$ (cfs)

T" = Width increment to be added

Constants = 0.97, 1.35, 1.19, 2.04, 0.96, 1.49

Note: Θ and τ_o are established as a function of sediment textural descriptions and particle size, shape and distribution characteristics [See Pages 172 to 175 of Chow, V.T., "Open Channel Hydraulics"]

II. EQUATIONS

$$Y_o = \frac{\tau_o}{0.97\ WS} \quad (1)$$

$$Y = Y_o \cos\left(\frac{\tan \Theta}{Y_o} x\right) \quad (2)$$

where $\frac{\tan \Theta}{Y_o}$ is in radians

$$T = 2x \text{ at } Y = 0 \quad (3)$$

$$V = \frac{1.35-1.19 \tan \Theta}{n} Y_o^{2/3} S^{1/2} \quad (4)$$

$$A = \frac{2.04\ Y_o^2}{\tan \Theta} \quad (5)$$

$$Q = AV \quad (6)$$

If Q'<Q, use

$$T' = 0.96 \left(1 - \sqrt{\frac{Q'}{Q}}\right) T \quad (7)$$

If Q''>Q, use

$$T'' = \frac{n\ (Q''-Q)}{1.49\ Y_o^{5/3} S^{1/2}} \quad (8)$$

III. EXAMPLE

A. Given

$\tau_o = 0.1$
$n = 0.035$
$\Theta = 25°$
$S = 0.0001$ ft./ft.
$Q = 1{,}000$ cfs

B. Calculations

Using equation (1),

$$Y_o = \frac{\tau_o}{0.97\ WS} = \frac{0.1}{(0.97)(62.4)(.0001)} = \underline{\underline{16.5 \text{ feet}}} \quad (a)$$

Solve for x at Y = 0 with equation (2)

$$Y_o \text{ Cos } \left(\frac{\tan \Theta}{Y_o} x\right) = Y = 0$$

$$\text{Cos } \left(\frac{\tan \Theta}{Y_o} x\right) = 0$$

$$\frac{\tan \Theta}{Y_o} X = 1.57$$

$$X = 1.57 \frac{Y_o}{\tan \Theta}$$

Resubstituting Y_o = 16.5 feet

$$X = 1.57 \frac{(16.5)}{.466} = 55.6 \text{ feet} \text{ ----------------- (b)}$$

Which by equation (3), gives

$$T = 2X = 2(55.6) = 111.2 \text{ feet} \text{ --------------- (c)}$$

and by equation (4),

$$V = \frac{1.35 - 1.19 \tan \Theta}{n} Y_o^{2/3} S^{1/2}$$

$$V = \frac{1.35 - 1.19\ (.466)}{.035} (16.5)^{2/3} (.0001)^{1/2}$$

$$V = 1.47 \text{ fps} \text{ ------------------------------------- (d)}$$

and by equation (5)

$$A = \frac{2.04\ Y_o^2}{\tan \Theta}$$

$$A = \frac{2.04\ (16.5)^2}{.466}$$

A = 1,190 SF ------------------------------------ (e)

The theoretical flow is calculated by equation (6), which yields

$$Q = AV$$

$$Q = 1,190\ (1.47)$$

Q = 1,750 cfs ------------------------------------ (f)

1000 cfs <1,750 cfs, equation (7) then gives

$$T' = 0.96\ \left(1 - \sqrt{\frac{Q'}{Q}}\right)T$$

$$= 0.96\ \left(1 - \sqrt{\frac{1,000}{1,750}}\right)(111.2)$$

= 26.1 feet ------------------------------------ (g)

Which provides a true width of

111.2 - 26.1 = 85.1 feet -------------------------- (h)

APPENDIX C

UNIT PRICES USED IN THIS REPORT

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UNIT PRICES USED IN THIS REPORT

Clearing Land:

1. Tree removal and restoration of vegetation along the bank -------------------------------- $10,000 per River Mile

Excavation:

1. Dredge bottom sludge hydraulically and deposit in dewatering cell -------------------- $2.50 per Cubic Yard in Place
2. Remove bank sludge with backhoe or drag-line and deposit in dump truck ---------------- $3.50 per Cubic Yard in Place

Dewatering Cell for Slurries:

1. Strip topsoil, form dikes, deposit sludge slurries and maintain cells ------------------ $1.50 per Cubic Yard of Sludge in Place
2. Re-use the cells, remove dewatered sludge and load into dump trucks; Restore land and revegetate ------------------------------- $0.75 per Cubic Yard of Sludge in Place

Hauling:

1. Sludge to landfill site ------------------------ $0.14 per ton-mile of material
   a. Bottom Sludge ------------------------------ $0.20 per Cubic Yard of Sludge in Place per haul mile
   b. Bank Sludge -------------------------------- $0.18 per Cubic Yard of Sludge in Place per haul mile
2. Iron Ore to point of sale --------------------- $0.14 per ton-mile of Ore

UNIT PRICES USED IN THIS REPORT

Landfill:

1. New Publicly Owned

Purchase land, remove and store topsoil, construct peripheral ditches, spread sludge, restore topsoil and vegetate	$1.00 per Cubic Yard deposited
a. Bottom Sludge	$0.44 per Cubic Yard of Sludge in Place
b. Bank Sludge	$1.00 per Cubic Yard of Sludge in Place

2. Deposit in Existing Private Landfill — $3.00 per Cubic Yard deposited

a. Bottom Sludge	$1.33 per Cubic Yard of Sludge in Place
b. Bank Sludge	$3.00 per Cubic Yard of Sludge in Place

Iron Salvage:

1. Process Sludge	$6.00 per Cubic Yard delivered
2. Sell Iron Ore	$33.00 per Ton of Free Iron contained

Temporary Easements:

1. Access to River or to Bank	$300 per Each
2. Dewatering Cells	$1,500 to $2,000 per Location
3. Working Zone on River Banks	$2,000 per River Mile

Note: In Place refers to the volume found as it presently exists in the river (in situ).

APPENDIX D

ABBREVIATIONS

acre-ft.	- acre feet
BKGD	- background
BOD_5	- 5 day biochemical oxygen demand
BOD_{20}	- 20 day biochemical oxygen demand
BPT	- best practical treatment
BTU	- British thermal unit
BTU/Lb.	- British thermal unit per pound
C	- escape coefficient
$CaCO_3$	- calcium carbonate
cfs	- cubic feet per second
cfs/SM	- cubic feet per second per square mile
CN	- cyanide
COD	- chemical oxygen demand
Cu.yds.	- cubic yards
°C	- degrees centigrade
Do	- initial oxygen deficit
DO	- dissolved oxygen
EPA	- Environmental Protection Agency
FMAM	- February, March, April, May
fps	- feet per second
Ft.	- feet
°F	- degrees fahrenheit
H & E	- Havens and Emerson
Hrs.	- Hours
Δh	- change in elevation
I.D.	- identification
JASO	- July, August, September, October
K	- reaeration coefficient
kg/l	- kilograms per liter
Lbs./Day	- pounds per day
mgd	- million gallons per day
mg/l	- milligrams per liter
mg/kg	- milligrams per kilogram
mg/SF Day	- million gallons per square foot per day
NH_3-N	- Ammonia nitrogen
O_2	- oxygen
pH	- logarithm (base 10) of the reciprocal of the hydrogen ion concentration
PO_4-P	- phosphorus as phosphate
%	- percent
Q	- flow
R.M.	- River Mile
SF	- square feet

APPENDIX D (CONT'D.)

ABBREVIATIONS

SG	- specific gravity
SM	- square miles
SS	- suspended solids
τ_o	- tractive force
t	- time of travel
$T_{max.}$	- temperature - maximum
TDS	- total dissolved solids
Temp.	- temperature
TKN	- total Kjedahl nitrogen
TOC	- total organic carbon
TS	- total solids
USEPA	- United States Environmental Protection Agency
USGS	- United States Geological Survey
VTS	- total volatile solids
$yds.^3/mile$	- cubic yards per mile

APPENDIX D

ABBREVIATIONS